

Neonatal Care
Pocket Guide
for Hospital Physicians

May 2010



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Note

This booklet is a concise version of the Neonatal Care Protocol for Hospital Physicians. Its small size makes it easier for service providers to consult in clinical settings, thus avoiding missed opportunities for care.

This booklet is not a substitute for the Neonatal Care Protocol, which is a more comprehensive manual that provides healthcare personnel with a deeper understanding of the subjects covered.

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List of Abbreviations

A/C	Assist/Control	CRBSI	Catheter related blood stream infection
ABR	Auditory brain stem response		
AGA	Appropriate for gestational age	CRP	C-reactive protein
		CS	Cesarean section
ALT	Alanine transaminase	CSF	Cerebrospinal fluid
ANC	Absolute neutrophil count	CT	Computed tomography
AOP	Anemia of prematurity	CVP	Central venous pressure
APTT	Activated partial thromboplastin time	D5W	Dextrose 5% in water
		D7.5W	Dextrose 7.5% in water
ASD	Atrial septal defect	D10W	Dextrose 10% in water
AST	Aspartate transaminase	DDH	Developmental dysplasia of the hip
ATN	Acute tubular necrosis		
AV block	Atrioventricular block	DIC	Disseminated intravascular coagulopathy
B/A ratio	Bilirubin/albumin ratio	DR	Delivery room
BP	Blood pressure	EA	Esophageal atresia
BPD	Bronchopulmonary dysplasia	EBM	Expressed breast milk
BUN	Blood urea nitrogen	ECF	Extracellular fluid
CAH	Congenital adrenal hyperplasia	ECG	Electrocardiogram
CBC	Complete blood count	ECMO	Extracorporeal membrane oxygenation
CDC	Centers for Disease Control		
Cfu	Colony forming unit	EEG	Electroencephalogram
CH	Congenital hypothyroidism	EH	Epidural hemorrhage
CHD	Congenital heart disease	ELBW	Extremely low birth weight
CHF	Congestive heart failure		
CK	Creatine kinase	EOS	Early onset sepsis
CLD	Chronic lung disease	ETCOc	End tidal carbon monoxide
CMV	Cytomegalovirus	ETT	Endotracheal tube
CNS	Central nervous system	FAOD	Fatty acid oxidation defect
CONS	Coagulase-negative staphylococci	FBM	Fetal breathing movements
		FDP's	Fibrinogen degradation products
CPAP	Continuous positive airway pressure	FE-Na	Fractional excretion of sodium
		FFA	Free fatty acids

List of Abbreviations

FFP	Fresh frozen plasma	I/E ratio	Inspiratory/expiratory ratio
FHR	Fetal heart rate	I/T ratio	Immature to total ratio
FIO ₂	Fraction of inspired oxygen	IAP	Intrapartum antimicrobial prophylaxis
G6PD	Glucose-6-phosphate dehydrogenase	IDM	Infant of a diabetic mother
GA	Gestational age	IEM	Inborn error of metabolism
GBS	Group B streptococci	IgG	Immunoglobulin G
GERD	Gastro-esophageal reflux disease	IM	Intramuscular
GFR	Glomerular filtration rate	IMV	Intermittent mandatory ventilation
GGT	Gamma-glutamyl transpeptidase	INR	International normalized ratio
GIR	Glucose infusion rate	IPH	Intraparenchymal hemorrhage
GIT	Gastrointestinal tract	IPPV	Intermittent positive pressure ventilation
GMH	Germinal matrix hemorrhage	ITP	Immune thrombocytopenic purpura
GSD	Glycogen storage disease	IUGR	Intrauterine growth restriction
GVHD	Graft versus host disease	IV	Intravenous
Hb	Hemoglobin	IVH	Intraventricular hemorrhage
HBIG	Hepatitis B immunoglobulin	IVIG	Intravenous immunoglobulin
HBsAg	Hepatitis B surface antigen	IWL	Insensible water losses
HBV	Hepatitis B virus	KMC	Kangaroo mother care
Hct	Hematocrit	L/P ratio	Lactate/pyruvate ratio
HCV	Hepatitis C virus	LBW	Low birth weight
HDN	Hemorrhagic disease of the newborn	LGA	Large for gestational age
HELLP	Hemolytic anemia, elevated liver enzymes and low platelet count	LOS	Late onset sepsis
HIE	Hypoxic-ischemic encephalopathy	LP	Lumbar puncture
HMD	Hyaline membrane disease	MAP	Mean airway pressure
HMF	Human milk fortifier	MAS	Meconium aspiration syndrome
Hrs	Hours	MCV	Mean corpuscular volume
HPA	Human platelet antigen	MEN	Minimal enteral nutrition
HSV	Herpes simplex virus	Min	Minute
		MRI	Magnetic resonance imaging

List of Abbreviations

MRSA	Methicillin resistant Staphylococcus aureus	PPHN	Persistent pulmonary hypertension
MSUD	Maple syrup urine disease	PPV	Positive pressure ventilation
MV	Mechanical ventilator	PSV	Pressure support ventilation
NCPAP	Nasal CPAP	PT	Prothrombin time
NEC	Necrotizing enterocolitis	PTV	Patient-triggered ventilation
NG tube	Nasogastric tube	PUV	Posterior urethral valve
NICU	Neonatal intensive care unit	PVD	Post-hemorrhagic ventricular dilatation
NKH	Non ketotic hyperglycemia	PVL	Periventricular leukomalacia
NNS	Non-nutritive sucking	PVHI	Periventricular hemorrhagic infarction
NO	Nitric oxide	q	Every (quaque)
NPO	Nothing per os	RBC's	Red blood cells
NRP	Neonatal Resuscitation Program	RR	Respiratory rate
NS	Normal saline	RDS	Respiratory distress syndrome
NST	Non-stress test	Rh factor	Rhesus factor
NTE	Neutral thermal environment	rh-EPO	Recombinant human erythropoietin
OR	Operation room	ROM	Rupture of membranes
Oz	Ounce	ROP	Retinopathy of prematurity
PaCO ₂	Partial arterial carbon dioxide pressure	RR	Respiratory rate
PaO ₂	Partial arterial oxygen pressure	SAH	Subarachnoid hemorrhage
PC	Pyruvate carboxylase	SaO ₂	Arterial oxygen saturation
PCR	Polymerase chain reaction	SC	Subcutaneous
PCV	Packed cell volume	SCM	Sternocleidomastoid muscle
PDA	Patent ductus arteriosus	SD	Standard deviation
PDH	Pyruvate dehydrogenase	SDH	Subdural hemorrhage
PIE	Pulmonary interstitial emphysema	SGA	Small for gestational age
PMA	Postmenstrual age	SGH	Subgaleal hematoma
PMN	Polymorphnuclear	SIADH	Syndrome of inappropriate antidiuretic hormone secretion
PN	Parenteral nutrition	SIDS	Sudden infant death syndrome
PNA	Postnatal age		
PO	Per-oral		

List of Abbreviations

SIMV	Synchronized intermittent mandatory ventilation	TSB	Total serum bilirubin
SIPPV	Synchronized intermittent positive pressure ventilation	TTN	Transient tachypnea of the newborn
SLE	Systemic lupus erythematosus	UAC	Umbilical artery catheterization
SSC	Skin to skin contact	UCB	Unconjugated bilirubin
SVT	Supraventricular tachycardia	UCD	Urea cycle defect
TAR	Thrombocytopenia with absent radii	UDPG-T	Uridine diphosphate glucuronyl transferase
TB	Tubercle bacillus	UTI	Urinary tract infection
TcB	Transcutaneous bilirubin	UVC	Umbilical vein catheter
Te	Expiratory time	V/Q	Ventilation perfusion
TEF	Tracheoesophageal fistula	VG	Volume guarantee
TGA	Transposition of the great arteries	VLBW	Very low birth weight
Ti	Inspiratory time	 VLCFA's	Very long chain fatty acids
TMS	Tandem mass spectrometry	VSD	Ventricular septal defect
TORCH	Toxoplasmosis, other, rubella, cytomegalovirus, and herpes simplex	Vt	Tidal volume
TPN	Total parenteral nutrition	VWD	Von Willebrand disease
		WBC	White blood cell
		Wk	Week

CHAPTER 1

Levels of Risk for Neonatal Care

All neonatologists and obstetricians should know the levels of risk for neonatal care in the delivery room (DR) and operation room (OR), and reach consensus about which deliveries will be attended by the resident or the specialist.

Table (1-1): Levels of Risk for Neonatal Care in the DR and OR

Level 0 (Low Risk)	
Identifying maternal fetal factors	<ul style="list-style-type: none"> • Uncomplicated pregnancy, labor & delivery
Personnel	<ul style="list-style-type: none"> • Doctor, or nurse, or medical staff
Equipment	<ul style="list-style-type: none"> • Routine equipment for resuscitation • Equipped radiant warmer
Level 1 (Mild to Moderate)	
Identifying maternal fetal factors	<ul style="list-style-type: none"> • Cesarean section • Meconium staining • Fetal distress • 32-36 weeks' fetus • >42 weeks' fetus • Intrauterine growth restriction (IUGR) • Multiple gestations • Breech delivery • Mild Rh disease* • Maternal illness • Suspected infection • Vaginal bleeding • General anesthesia

Table (1-1): Levels of Risk for Neonatal Care in the DR and OR (Cont'd)

	<ul style="list-style-type: none"> • Sedative narcotics administration • Polyhydramnios • Oligohydramnios
Personnel	<ul style="list-style-type: none"> • Neonatal resident, plus a neonatal care nurse
Equipment	<ul style="list-style-type: none"> • Routine equipment for resuscitation • Equipped radiant warmer • Emergency cart • Cardiorespiratory and BP monitor
Level 2 (Severe Risk)	
Identifying maternal fetal factors	<ul style="list-style-type: none"> • <32 weeks' fetus • Known anomalies affecting transition • Severe Rh disease* • Any level 1 fetus with complications
Personnel	<ul style="list-style-type: none"> • Neonatal specialist, plus a neonatal care nurse
Equipment	<ul style="list-style-type: none"> • Routine equipment for resuscitation • Equipped radiant warmer • Emergency cart • Cardiorespiratory and BP monitor

BP: blood pressure

*The severity of Rh disease during pregnancy can be identified by maternal antibody screening. Regular ultrasound of the fetus is performed to detect fetal hydrops.

CHAPTER 2

Neonatal Resuscitation

The majority of, but not all, neonatal resuscitations can be anticipated by identifying the presence of antepartum and intrapartum risk factors associated with the need for neonatal resuscitation (Table 2-1).

Table (2-1): Antepartum and Intrapartum Risk Factors

Antepartum Risk Factors	Intrapartum Risk Factors
<ul style="list-style-type: none"> • Rupture of membranes for a period of ≥ 18 hrs • Pre-eclampsia and eclampsia • Maternal infection – Malaria, HIV • Premature labor • Multiple births 	<ul style="list-style-type: none"> • Excessive bleeding • Breech presentation • Meconium staining amniotic fluid • Non-reassuring fetal heart rate patterns (e.g., lost beat to-beat variability, late deceleration, bradycardia) • Prolapsed or nuchal cord • Rapid, hard labor • Foul-smelling amniotic fluid • Prolonged labor • Shoulder dystocia

Personnel and Equipment

Personnel

- Every delivery should be attended by at least one person whose only responsibility is the baby; this person should have the skills required to perform a complete resuscitation.
- When resuscitation is anticipated, additional personnel should be present in the DR or OR before the delivery.

Essential equipment and supplies

Table (2-2): Equipment and Supplies for Neonatal Resuscitation

Suction equipment	<ul style="list-style-type: none"> • Bulb syringe • Mechanical suction & tubing (-ve pressure should not exceed 100 mmHg) • Suction catheters (5, 6, 8, 10Fr) • Meconium aspirator
Bag and mask equipment	<ul style="list-style-type: none"> • Self-inflating bag (250 -750ml) with a pressure-release valve, and a reservoir • Face masks (term & preterm sizes) • Oral airways (term & preterm sizes) • Oxygen source with flowmeter & tubing (flow 5-8 L/min)
Intubation equipment	<ul style="list-style-type: none"> • Laryngoscope with straight blades (No. 0, 1) & a bright light • Extra bulbs and batteries • ETT (2.5, 3.0, 3.5, 4.0 mm) • Stylet (if available) • Scissors
Umbilical vessel catheterization supplies	<ul style="list-style-type: none"> • Scalpel or scissors • Povidone-iodine solution • Umbilical tape • Umbilical catheters (3.5, 5Fr) • Three-way stopcocks
Medications	<ul style="list-style-type: none"> • Epinephrine (1:10,000 solution) • Volume expanders: normal saline and Ringer's lactate • D10W solution & sterile water • Naloxone hydrochloride
Miscellaneous	<ul style="list-style-type: none"> • Radiant warmer • Sterile gloves • Stethoscope (infant-sized head) • Feeding tubes (6, 8Fr) • Adhesive tape (½ or ¾ inch)

Table (2-2): Equipment and Supplies for Neonatal Resuscitation (Cont'd)

	<ul style="list-style-type: none"> • Syringes (1, 3, 5, 10, 20, 50 ml) • Needles (25, 21, 18 gauge) • T connectors and stopcocks • Warm linens • Clock • Thermometer • Cardiac monitor or pulse oximeter (optional)
--	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

N.B.: Pulse oximetry should be available for premature infant.

Initial Assessment

- The following questions must be asked:
 - ▶ Term gestation?
 - ▶ Clear amniotic fluid?
 - ▶ Breathing or crying?
 - ▶ Good muscle tone?
- If the answer to any of these questions is “No”, resuscitation should be started.
- Resuscitation should proceed rapidly:
 - ▶ You have ≈30 seconds to achieve a response from one step before deciding whether you need to go on to the next step.
 - ▶ Evaluation and decision-making are based primarily on respiration, heart rate, and color.

Steps of Neonatal Resuscitation

The Apgar score is not used to determine when to initiate resuscitation or in making decisions about the course of resuscitation.

Initial steps

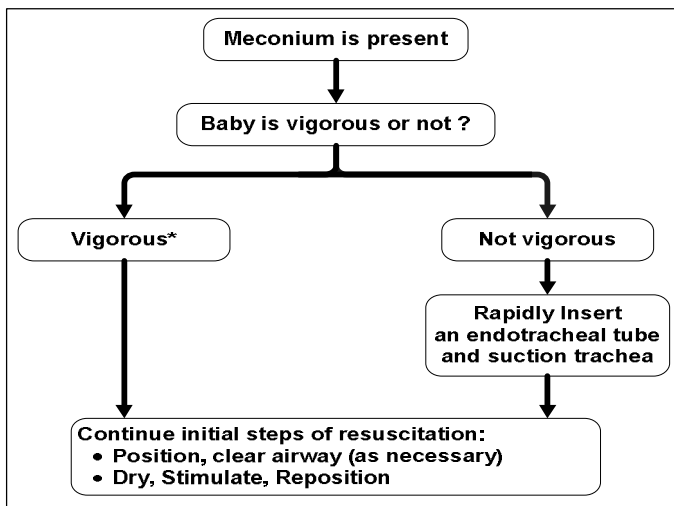
- Provide warmth by placing the infant under a radiant warmer.
- Dry the infant thoroughly and gently; the wet towels should be promptly removed.

- **Position** head and **clear airway** as necessary by placing the newborn on the back with head in midline position and with slight neck extension "sniffing position". Suction the mouth first, and then the nose (M before N) gently and briefly by suction bulb or a large-bore suction catheter. Limit suctioning to 5 seconds at a time and avoid aggressive & deep pharyngeal suctioning.

Steps of neonatal resuscitation

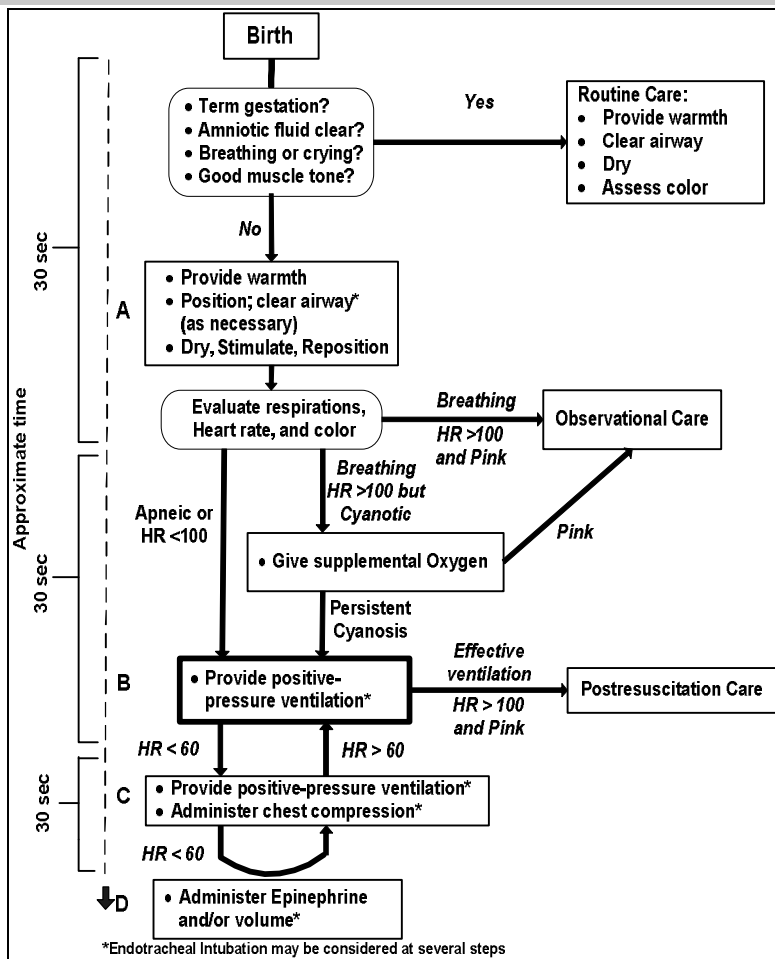
Initial steps of resuscitation in presence of meconium staining are demonstrated in (Figure 2-1).

An algorithm for steps of resuscitation is illustrated in (Figure 2-2).



*Vigorous → has strong respiratory effort, good muscle tone, and heart rate >100 beats/min

Figure (2-1): Initial steps of resuscitation in presence of meconium



HR: heart rate

Figure (2-2): Neonatal resuscitation flow chart

Reproduced with permission from American Heart Association and American Academy of Pediatrics. Neonatal Resuscitation Guidelines, Pediatrics 2006; 117(5): e1029- 38.

Stimulation of the infant to breathe

Apply tactile stimulation by slapping or flicking the soles of the feet or by gently rubbing the back once or twice.

Evaluation

Evaluate respiration, HR (counted in 6 seconds x 10) & color.

Positive pressure ventilation (PPV)

- Use a resuscitation self-inflating bag with a reservoir.
- Select appropriate-sized mask; it should cover tip of chin, mouth and nose and not eyes.
- Be sure airway is clear; position infant's head in sniffing position by placing a small roll under the shoulders, and position yourself at infant's side or head. An airtight seal is essential.
- Rhythm: breathe, two, three, breathe, two, three.....
- Rate: 40-60/min.
- Pressure: the lowest pressure required to move the chest adequately (first few breaths often require higher pressures and longer inflation time than subsequent breaths).
- Do not allow your fingers to rest on the infant's eyes, and do not let the mask go down.
- Improvement is indicated by ↑HR, improved color, muscle tone and spontaneous breathing.
- If no improvement, attempt the following:
 - ▶ Reapply mask to face using light downward pressure and lifting the mandible up toward the mask.
 - ▶ Reposition the head.
 - ▶ Check for secretions; suction mouth and nose.
 - ▶ Ventilate with the infant's mouth slightly open.
 - ▶ Increase pressure of ventilations.
 - ▶ Recheck or replace the resuscitation bag.
 - ▶ Consider endotracheal intubation.
- Insert an orogastric tube if PPV with a mask is required for longer than several minutes.

Chest compression

- Two persons; one to perform chest compression and the other to continue ventilation.
- Methods:
 - ▶ Two-thumb encircling hands method: stand at the infant's foot and grip the chest in both hands; the 2 thumbs press at the junction of the middle and lower thirds of the sternum (just below an imaginary line joining the nipples); with the fingers wrapped around and supporting the back.
 - ▶ Two-finger method: stand at the infant's side and compress the lower third of the sternum with the index and third fingers of one hand; with the other hand supporting the back.
- Rhythm: the compressor repeats "One-and-Two-and-Three-and-Breathe-and..."
- Rate: breathing rate (30 breaths/min), and compression rate (90 compressions/min) (3 compressions & 1 breath take 2 seconds).
- Compression depth: $\frac{1}{2}$ of the chest diameter.
- Duration of downward stroke of the compression is shorter than the duration of the release.
- Thumbs or fingers remain in contact with the chest at all times, and chest compressions and ventilation are well coordinated.

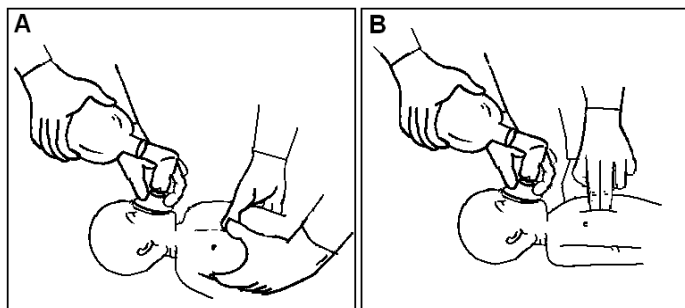


Figure (2-3): The two-thumb encircling hands method for chest compressions (A) is preferred over the two-finger method (B)

Endotracheal intubation

- Time limit: should be completed within 20 seconds.
- Endotracheal tube size: based on weight (**Table 2-3**).

Table (2-3): Endotracheal Tube (ETT) Sizes

Gestational age (weeks)	Weight (gm)	Tube Size (mm)	Distance of Tip of ETT
<28	<1,000	2.5	7 cm
28-34	1,000-2,000	3.0	8 cm
34-38	2,000-3,000	3.5	9 cm
>38	>3,000	3.5-4	10 cm

- Steps for intubation:
 - ▶ Stabilize the newborn's head in the "sniffing" position.
 - ▶ Deliver free flow oxygen during the procedure.
 - ▶ Cut the tube to a shorter length (13-15 cm).
 - ▶ Slide the laryngoscope over the right side of the tongue, pushing the tongue to the left side of the mouth, and advancing the blade until the tip lies just beyond the base of the tongue, lift the blade slightly and raise the entire blade (not just the tip).
 - ▶ Look for landmarks; vocal cords should appear as vertical stripes on each side of the glottis or as an inverted letter "V".
 - ▶ Suction, if necessary, for visualization.
 - ▶ Hold the tube with the right hand, insert into the right side of the mouth with the curve of the tube lying in the horizontal plane, and then pass it between the vocal cords \approx 2 cm below the glottis (the tip of the tube is inserted until the vocal cord guide is at the level of the cords). If the vocal cords are closed, wait for them to open.
 - ▶ Be certain that you visualize the glottis before inserting the tube, watch the tube enter between the vocal cords.

- ▶ Hold the tube firmly against the infant's palate while removing the laryngoscope, and hold the tube in place while removing the stylet (if used).
- ▶ Estimate the proper depth of insertion by:

Weight (kg) + 6 cm = insertion depth at lip in cm

- Confirm the position of the tube by:
 - ▶ Observing symmetrical chest wall movement.
 - ▶ Listening for bilateral equal breath sounds.
 - ▶ Confirming absence of gastric inflation.
 - ▶ Watching a fog of moisture in the tube during exhalation.
 - ▶ Noting improvement in HR, color & activity.
 - ▶ Chest x-ray confirmation, if the tube is to remain in place past initial resuscitation.

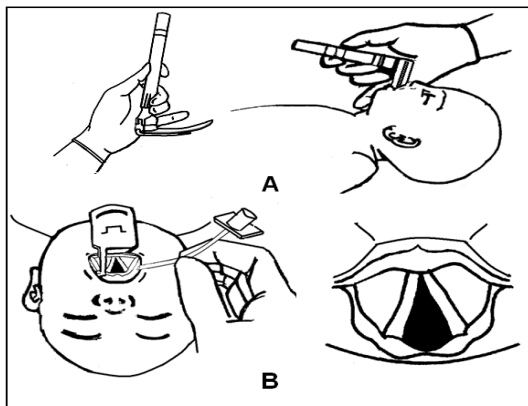


Figure (2-4): Endotracheal intubation

A) Holding and lifting the laryngoscope blade, B) Identification of landmarks, and endotracheal tube insertion

N.B.: Ventilation of the lungs is the single most important and most effective step in resuscitation of the compromised newborn.

Medications

Epinephrine

- Route: IV (through umbilical vein). Consider ET route while IV access is being established
- Dose: 0.1-0.3 ml/kg (higher dose, 0.3-1 ml/kg, for ET route); can be repeated after 3-5 min.
- Preparation: 1:10,000 solution
- Rate: rapidly; as quickly as possible

Volume expansion

- Normal saline, Ringer's lactate, or O –ve blood packed RBCs
- Route: umbilical vein
- Dose: 10 ml/kg (another dose may be needed)
- Rate: slowly (over 5-10 min)

Sodium bicarbonate

- **Do not** give unless the lungs are adequately ventilated
- Route: umbilical vein (**should not** be given through the ETT)
- Dose: 2 mEq/kg (8.4% concentration)
- Dilute 1:1 with D5W or sterile water (0.5 mEq/ml)
- Rate: slowly, **not** >1 mEq/kg/min.

Naloxone

- If a mother has received narcotics within 4 hrs of delivery and her infant fails to breathe → 1st assist ventilation with PPV, and then consider giving naloxone.
- Dose: 0.1 mg/kg, 1mg/ml solution (IV or IM)

Special Considerations

Choanal atresia (bilateral)

- Place an oral airway.
- ETT, inserted through the mouth, may be needed.

Pierre Robin syndrome

- Insert a nasopharyngeal tube and place the infant prone.

Pneumothorax

- Detect by transillumination and insert a needle in the chest.

Diaphragmatic hernia

- If suspected (persistent respiratory distress, scaphoid abdomen & ↓breath sounds on the side of the hernia) → avoid PPV by mask, intubate trachea immediately & insert an orogastric tube.

Resuscitation of preterm newborns

- Prepare additional resources for an anticipated preterm labor
 - ▶ Additional trained personnel
 - ▶ Careful attention for maintaining temperature
 - ▶ Compressed air
 - ▶ Oxygen blender
 - ▶ Pulse oximetry
- Use an oximeter and blender to achieve SaO_2 in the 85-93% range during and immediately following resuscitation.
- Handle the infant gently.
- Avoid Trendelenburg position.
- Avoid high airway pressures, if possible.
- Avoid rapid IV fluid boluses and hypertonic solutions.
- After resuscitation
 - ▶ Monitor and control blood glucose level.
 - ▶ Monitor for apnea, bradycardia, or oxygen desaturation.
 - ▶ Monitor and control oxygenation & ventilation.
 - ▶ Delay feeding, if perinatal compromise was significant.
 - ▶ Increase suspicion for infection.

Routine Care after Stabilization of Newborn

- Umbilical cord care
 - ▶ Fix the cord clamp 3-5 cm away from the umbilicus, and cut the cord using a scalpel.
 - ▶ Examine for any abnormality (single umbilical artery).
 - ▶ Wipe the umbilical stump with ethyl alcohol 70%.

Chapter 2: Neonatal Resuscitation

- Administer vitamin K₁, 0.5-1 mg IM.
- Apply antibiotic eye drops or ointment.
- Initiate breastfeeding within a few minutes of delivery.
- Encourage "rooming-in" to keep mother and baby together.

N.B.: Discontinuation of resuscitation may be appropriate if no signs of life (no HR and spontaneous breaths) in an infant after 15 min of complete and adequate resuscitation effort, with no evidence for other causes of newborn compromise.

CHAPTER 3

Care of the Well Newborn

Delivery Room Care

- Place the infant skin to skin with the mother, once he is stable.
- Assess the Apgar score, at 1 and 5 min after birth.
- Perform a brief physical examination to check that the infant is healthy (has no major anomalies or birth injuries, his/her tongue & body appear pink, and has normal breathing).
- Examine the hips to rule out dislocation (**Refer to Chapter 33**).
- Umbilical cord care (**Refer to Chapter 2**).
- Identification: take footprints and record in the medical record, and place 2 bracelets with identical hospital numbers (one on the wrist and the other on the ankle).

Transitional Care (first 4-6 hrs after birth)

- Common signs of disordered transitioning
 - ▶ Respiratory distress
 - ▶ Poor perfusion with cyanosis or pallor
 - ▶ Need for supplemental oxygen
 - ▶ Hypothermia
- Evaluate every 30-60 min
 - ▶ Assess HR, RR, axillary temperature, color & tone.
- With suspicion of disordered transitioning
 - ▶ If stable → observe closely for a period of time.
 - ▶ If persistent signs → transfer to a higher level of care.

Routine Care

- Keep newborn with mother all the time (rooming-in).
- Perform proper hand washing before handling the newborn.

Chapter 3: Care of the Well Newborn

- Maintain newborn's temperature
 - ▶ Encourage skin to skin contact with the mother
 - ▶ Use hats and proper clothes
- Assess GA using the expanded Ballard Score. Measure and record the newborn's weight, head circumference, and length, and then plot against the estimated GA.
- Bathing
 - ▶ Do not bathe immediately after birth; vernix caseosa does not need to be removed.
 - ▶ The first bath can be given with non-medicated soap and warm tap water once infant's temperature has stabilized (4-6 hrs after delivery).
 - ▶ Do not bathe the infant in a basin until after the umbilical stump has fallen off.
- Examine skin for trauma or signs of infection.
- Umbilical cord care
 - ▶ Keep the cord dry and loosely covered with clean sterile gauze.
 - ▶ Fold the diaper below the umbilicus.
 - ▶ If soiled, wash with soap and clean water and dry it well.
 - ▶ Apply alcohol after each diaper change.
- Place the newborn infant supine (on the back) to sleep and not prone (on the stomach).
- Routine medications
 - ▶ Apply antibiotic eye drops within 1 hr of delivery.
 - ▶ Give vitamin K₁ (0.5-1 mg IM) within 2 hrs of life.
- Feedings
 - ▶ Support immediate and exclusive breastfeeding during the first hr postpartum preferably in the DR.
 - ▶ Offer standard term formula to infants for whom breast-feeding is contraindicated at least every 3-4 hrs.

Instructions to the Mothers or Other Care-Givers

- Observe baby's temperature, respiration & effort at feeding.

- Observe for passage of urine and stools.

Newborn Male Circumcision

- Tests to exclude a bleeding disorder should be done.
- Contraindications: sick or unstable infant, congenital bleeding disorder (except after giving the specific therapy to the infant), and anomalies (e.g., hypospadias, ambiguity, or micropenis)
- After circumcision: apply a gauze dressing with petroleum jelly or an antibiotic cream, remove at the first diaper change, and apply a new dressing. Keep the penis clean with soap and water.

Screening

- Congenital hypothyroidism screening (3rd to 7th day of life)
- Bilirubin screening is recommended before discharge.

Parental Education

- Instruction by the nurse on feeding and infant care.
- Distribution of books and pamphlets on care of newborn.

Vaccination

- Educate parents about vaccination schedule.
- Administer HBIG (0.5 ml/kg IM) to all newborns of HBs Ag-positive mothers as soon as possible after birth (within 12 hrs), followed by HBV vaccine (0.5 ml IM).

Discharge Examination

- Answer any questions
- Observe for jaundice, skin infection, signs of illness (fever, lethargy and change in feeding behavior), and adequacy of breast milk intake.

Pediatric Follow-up Appointment

- Give follow-up date, 2-3 days after discharge.
- Give copies of initial and discharge summaries to the parents.

CHAPTER 4

Levels of Neonatal Care Units

Level I-Basic Neonatal Care

This level is for normal, stable, full term infant (body weight $\geq 2,500$ gm), with no risk factors.

Level II-Special Neonatal Care Units

Criteria for admission

- Preterm infant 32 weeks' gestation (<37 weeks)
- LBW infant $\geq 1,500$ gm
- Infant of a diabetic mother (IDM)
- Affected infant born to a high risk pregnancy and delivery
- Respiratory distress not needing assisted ventilation
- Hyperbilirubinemia, needing phototherapy
- Neonatal sepsis
- Hypothermia

Level III-Neonatal Intensive Care Units (NICU)

Criteria for admission

- Infant with hemodynamic compromise (shock)
- Moderate or severe respiratory distress, needing short-term mechanical ventilation for <7 days
- VLBW infant ($<1,500$ gm)
- Infant with an abnormal neurologic examination
- Infant with seizures or severe hypoxic-ischemic injury
- Infant requiring an exchange transfusion for hyperbilirubinemia or polycythemia
- Total parenteral nutrition for <7 days

Level IV- NICU (University Hospitals)

Criteria for admission

- ELBW infant (<1,000 gm)
- Prolonged mechanical ventilation for >7 days
- Surgery; pre and postoperative care
- Suspected metabolic or endocrine disorders
- Hydrops fetalis
- Life threatening anomalies
- Total parenteral nutrition for >7 days

CHAPTER 5

Stabilization Guidelines

Anticipate, promptly recognize, and correct any arising problem.

Airway and Breathing (Refer to Chapter 2)

A patent airway is of primary importance during stabilization

Thermoregulation (Refer to Chapter 9)

Circulatory Status

- Assess the circulatory status & perinatal volume loss
 - ▶ Capillary refill time (>3 seconds), pallor, mottling, cool skin, ↓peripheral pulses with poor peripheral perfusion
 - ▶ Tachycardia or bradycardia
 - ▶ BP: may be normal or low (↓BP is a late sign of shock)
 - ▶ Urine output
 - ▶ Blood gas analysis: evaluate for acidosis/hypoxemia
- Obtain an IV access (peripheral IV line is the 1st choice, and umbilical vein catheter is the 2nd choice).
- Treat circulatory failure
 - ▶ Support oxygenation/ventilation.
 - ▶ Give NS, Ringer's solution, blood 10 ml/kg over 15-30 min (repeat up to 2 times in severe shock).
 - ▶ Improve myocardial contractility
 - Dopamine: 5-20 µg/kg/min (continuous infusion).
 - Consider dobutamine or epinephrine.

Metabolic and Fluid status

- Monitor & maintain blood glucose levels at 50-125 mg/dl.
- In case of symptomatic hypoglycemia, give 2 ml/kg D10W IV over 1 min, followed by IV infusion of 4-8 mg/kg/min.

- Calculate fluid requirement according to GA, day of life, hydration state and disease state.
- Evaluate blood gases for acid-base balance. Administration of NaHCO_3 is limited to situations where:
 - ▶ Provision of adequate ventilation has been assured.
 - ▶ Tissue oxygenation and perfusion are maximized and the blood pH remains <7.20 and base deficit >10 .
 - ▶ Documented or suspected metabolic acidosis diagnosed during cardiopulmonary resuscitation.

NaHCO_3 (mEq) =

$$\text{Body weight (kg)} \times \text{HCO}_3 \text{ Deficit (Desired - Actual)} \times 0.3$$

Administer $\frac{1}{2}$ of the calculated dose, infuse over >20 -30 min, and then assess the need for the remainder.

Evaluate for Sepsis

- Review potential risk factors for sepsis (**Refer to Chapter 24**).
- Obtain CBC with differential & blood culture.
- Treat suspected infection
 - ▶ Initiate IV antibiotics (ampicillin + gentamicin) after obtaining the appropriate cultures.
 - ▶ Observe until results of blood culture are available.

CHAPTER 6

Neonatal Referral and Transport

Indications for Maternal/Neonatal Referral

A) Referral of the pregnant mother to

A hospital with level III NICU

When the mother is suspected to deliver a baby with:

- VLBW (<1,500 gm) or GA <32 weeks
- Anomalies affecting transition (e.g., diaphragmatic hernia)
- Severe hemolytic jaundice
- Any level I risk baby with complications (**Refer to Chapter 1**)

A hospital with level IV NICU

When the mother is suspected to deliver a baby with:

- ELBW (<1,000 gm)
- Anomalies needing immediate surgical intervention
- Life threatening anomalies
- Hydrops fetalis

B) Referral of the newborn infant to Level III or level IV neonatal care units (Refer to Chapter 4)

C) Referral of the neonate to another hospital

If procedures needed are unavailable at referring hospital

Arranging for Transport

A) Communication

Communication with the referral center is done to ensure the availability of an incubator and availability of the services required for the baby. Information that should be available:

- Parent's consent for referral documented in the medical record

- Infant's name and date of birth
- Names of the infant's mother and father
- Prenatal history
- Labor and Delivery Record
- Neonatal Resuscitation Record and Apgar scores
- GA and birth weight
- Vital signs (temperature, HR, RR & BP)
- Oxygen/ventilatory support requirements
- Laboratory data (glucose, calcium, Hct, blood gases)
- Vascular access

B) Role of the referring hospital

Stabilization of the newborn (Refer to Chapter 5)

Special considerations

- Esophageal atresia and tracheo-esophageal fistula: place a multiple end-hole suction catheter in the proximal pouch and put on to intermittent suction immediately.
- Diaphragmatic hernia: initiate immediate endotracheal intubation (**avoid bag and mask ventilation**), then insert a large NG tube into the stomach and aspirate its contents.
- Abdominal wall defects: cover the sac with warm, sterile, saline-soaked gauze, wrap with a sterile transparent plastic bag (take care to avoid bowel twisting & infarction), then inset a NG tube.
- Myelomeningocele: keep the newborn in the prone position; place a sterile saline-moistured gauze sponge over the defect. **Use latex free gloves** (risk of anaphylaxis).
- Bilateral choanal atresia: insert an oral airway.
- Pierre Robin syndrome: place the infant in the prone position. Use nasopharyngeal tubes in more severe cases.

Discussion

Discuss the newborn's condition and potential therapies with team members before departure.

Documentation

Document all newborn's data in the referral report.

C) Role of the receiving hospital

Prior to infant arrival (preparation of the place)

- Ensure presence of vacant incubator.
- Get an updated report (phone call) for case progress from the referring place, anticipate respiratory needs and ask the nurse to prepare needed equipment.

Upon arrival to the hospital

- Assess and stabilize the newborn (**Refer to Chapter 5**)
- Check the referral documents
 - ▶ Referral letter for case progress
 - ▶ Investigations and radiology
 - ▶ Medications given, doses and time of last given dose
 - ▶ Steps and procedures done in the referring hospital
 - ▶ Fill in the relevant part of referral sheet
- Fill in the Admission Sheet
- Ensure contacting the parents for:
 - ▶ Re-evaluating the history
 - ▶ Discussing the plan of care
 - ▶ Getting contact information (phone and address)
 - ▶ Getting consent for procedures
 - ▶ Highlighting the importance of family visits, breast-feeding and **regular breast milk expression**
 - ▶ Orientation to system of NICU visits

D) Feedback

Feedback can be obtained through a communication between the receiving hospital and the referring one to know the infant's status & the progression of the illness.

CHAPTER 7

Newborn Admission in Neonatal Care Units

Any infant that is causing concern to such a degree that the attending doctor feels that the infant requires observation or treatment should be admitted. It is better for an infant to be admitted unnecessarily than for an infant requiring admission to be left on the ward.

Admission Process

- Obtain full history from parents
- Perform complete and thorough clinical examination
- Provide standard orders for management of each neonate. All admitting orders are reviewed and modified by the physician, as needed. List of standard admitting orders:
 - ▶ Place of admission: incubator or crib depending on weight and clinical condition.
 - ▶ Checking vital signs every 30 min for the 1st 2 hrs, then every hour until stable, and then every 4 hrs.
 - ▶ Assessing weight, length and head circumference, and estimating GA, then plotting these measures against GA.
 - ▶ Bedside glucose monitoring until stable.
 - ▶ Antibiotic eye drops administration within 1 hr after birth.
 - ▶ Vitamin K₁ administration within 1-2 hrs after birth.
 - ▶ Recording weight daily.
 - ▶ Nutritional plan: breastfeeding on demand is the usual order; or any other special fluid or nutrition order needs to be specified and documented.
 - ▶ Bathing the neonate when generally and vitally stable and after his/her temperature is stable for at least 2 hrs.
 - ▶ Provision of umbilical cord care

- ▶ Admitting procedures
 - Completion of the Data Collection Forms
 - Completion of the Admission Log Book
 - Completion of the Daily Neonatal Clinical Record
 - Notification of hospital administration of admission
 - Orientation of parents to NICU routines
- ▶ Determination of specific interventions based on the neonate's risk factors and assessment, examples:
 - Daily measurement of head circumference for suspected hydrocephalus.
 - Assessment of abdominal circumference every 6-8 hrs for suspected NEC.

CHAPTER 8

Physical Assessment of the Newborn

Time of Examination

- As soon as possible after delivery
 - ▶ Assess infant's temperature, HR, RR, color, type of respiration, tone, activity, and level of consciousness every 30 min after birth for 2 hrs or until stabilized.
 - ▶ For high-risk deliveries, this should take place in the DR and focus on congenital anomalies and problems that may interfere with adaptation to extrauterine life.
- After a stable delivery (a 2nd examination within 24 hrs of birth).
- Before discharge from the maternity unit or NICU.
- Whenever there is any concern about the infant's progress.

Remember

- Wash your hands before examination.
- It is better to perform examination in a fixed order. However, if the infant is quiet and relaxed at the beginning of examination, palpation of the abdomen or auscultation of the heart should be performed first before other more disturbing manipulations.
- Whenever possible, the infant's mother should be present.
- The environment should be warm with a good light source.
- The infant should be completely undressed.
- Make sure to document the assessment appropriately.

Physical Examination

GA assessment

Vital signs

- Stable growing neonates: assess before feeding time.

Chapter 8: Physical Assessment of the Newborn

- Unstable and mechanically ventilated neonates: assess at least every 1-2 hrs.

Temperature

- Obtain temperature as axillary temperatures.
- Normal temperature for a neonate is 36.5-37.5°C.

Heart rate

- Assess HR by auscultation and counting for a full minute.
- Normal HR in neonates is 120-160 beats/min at rest.
- If tachycardia (HR >170 beats/min): make sure that the neonate is not crying or moving vigorously.
- If bradycardia (HR <100 beats/min): assess color & pattern of breathing; start bag and mask ventilation, if necessary. Bradycardia is sometimes normal in term sleeping neonates.
- Palpate peripheral pulses of upper & lower limbs (to rule out coarctation of aorta).

Respiratory rate

- Obtain RR by observation for one full minute.
- Normal RR of a neonate is 40-60 breaths/min.
- Newborns have periodic breathing; apnea is abnormal.

Blood pressure

- Measure BP in all 4 limbs using “DINAMAP” machine.
- BP varies with activity (↑with crying & ↓with sleeping).
- Appropriate cuff size should cover only ⅔ of upper arm.
- Normal BP varies with GA and PNA (**Refer to Appendix 6**).
- Lower limbs systolic pressure < upper limbs systolic pressure by 6-9 mmHg, may indicate coarctation of aorta.

Growth measurements

Weight

- Obtain weight every day (twice daily, if infant <1,000 gm), at a fixed time of the day, in conjunction with routine care and isolette cleaning, and then plot on the weight chart.

- If significantly different from the previous day, check twice.
- Do not weigh, if the infant is too unstable to be moved.

Length

- Obtain crown-to-heel length on admission and weekly.
- Plot length on the length chart weekly.

Head circumference

- Obtain head circumference on admission and weekly.
- Place a tape measure around the head to encircle the occiput, the parietal bones, and the forehead (1 cm above the nasal bridge), i.e. the largest circumference.
- Measure at least daily in neonates with neurological problems (e.g., IVH, hydrocephalus or asphyxia).

General appearance

Observe & record activity, skin color, & obvious congenital abnormalities.

Skin

- Color: pink, jaundice, pallor, plethora or acrocyanosis
- Texture: dry, wrinkled, covered with vernix caseosa; superficial peeling is common in the 1st wk of life
- Non pathologic conditions: millia, erythema toxicum, mongolian spots, benign pustular melanosis & lanugo hair.
- Abnormal conditions: petechiae, bruising, hemangioma, port wine stains, pigmented nevi & forceps marks.

Head and Neck

Table (8-1): Head and Neck Assessment Parameters

Parameter	Normal	Abnormal
Skull	<ul style="list-style-type: none"> • Molding • Caput succedaneum • Craniotabes • Anterior fontanelle (2.5-3 cm) 	<ul style="list-style-type: none"> • Cephalhematoma • Fracture • Sutures fused • Fontanelle (full or depressed)*
Face	<ul style="list-style-type: none"> • Normal configuration 	<ul style="list-style-type: none"> • Face asymmetry • Abnormal (odd) facies

Table (8-1): Head and Neck Assessment Parameters (Cont'd)

Parameter	Normal	Abnormal
		<ul style="list-style-type: none"> • Mandibular hypoplasia • Forceps injury • Facial palsy
Eyes	<ul style="list-style-type: none"> • Symmetrical • Open • Red reflex (by ophthalmoscope) 	<ul style="list-style-type: none"> • Asymmetry • Subconjunctival hemorrhage • Corneal opacities • Cataracts • Coloboma • Congenital glaucoma (large and cloudy) • Conjunctivitis
Nose	<ul style="list-style-type: none"> • Symmetrical • Patent 	<ul style="list-style-type: none"> • Deformity • Nasal flaring • Choanal atresia
Ears	<ul style="list-style-type: none"> • Normal configuration (shape and perpendicularity to skull) • Response to sound 	<ul style="list-style-type: none"> • Abnormal configuration • Low set • No response to sound • Forceps injury • Accessory auricle(s)/tags
Mouth	<ul style="list-style-type: none"> • Normal configuration • Epstein's pearl 	<ul style="list-style-type: none"> • Cleft lip/palate • High arched palate • Precocious teeth • Macroglossia • Tongue tie
Neck	<ul style="list-style-type: none"> • Normal mobility 	<ul style="list-style-type: none"> • Webbing • Masses (sternomastoid tumor goiter, or cystic hygroma) • Fracture clavicle

* Fontanelle may be bulging during crying; examine when the baby is quiet.

Extremities

Observe and examine for:

- Polydactyly, syndactyly, abnormal palmar creases & talipes.

- Developmental dysplasia of the hip (DDH), palsies (e.g., Erb's palsy) and fractures (swelling and crepitus).

Back and spine

Palpate the entire spine and examine for:

- Scoliosis
- Pilonidal sinus
- Spinal defects: meningocele, lipoma, or tuft of hairs

Lymph nodes

Palpable lymph nodes are found in 1/3 of normal neonates (<12 mm, often in inguinal, cervical areas and occasionally axillary area).

Genitalia

Table (8-2): Genital Assessment

Parameter	Normal	Abnormal
Female	<ul style="list-style-type: none"> • Normal configuration • Mucous vaginal discharge • Grayish white mucoid vaginal discharge • Pseudo-menstruation • Mucosal tag from the vaginal wall 	<ul style="list-style-type: none"> • Ambiguous genitalia • Labia fused • Imperforate hymen
Male	<ul style="list-style-type: none"> • Normal configuration • Testes in scrotum • Hydrocele • Penile length 2.5 cm • Retractable testes 	<ul style="list-style-type: none"> • Ambiguous genitalia • Phimosis • Hypospadias • Epispadias • Undescended testes

Anus and rectum

- Check patency (using a soft catheter), position and size (normal diameter is 10 mm).
- Abnormalities: imperforate anus, fistula, or patulous.

Systems assessment

Neurological assessment [Tables (8-3) & (8-4)]

- Perform a full assessment every day (more frequently for unstable neonates and those with neurological problems).

Table (8-3): Neonatal Neurological Assessment Parameters

Parameter	Comments
Activity	• Quiet, awake, irritable or sleeping
Level of consciousness	• Lethargic, alert or sedated
Posture	• Observe neck position, look for symmetry between the sides and compare the upper & lower extremities
Movements	• Spontaneous, to pain or absent
Tone	• Hypertonic, hypotonic, normal or weak
Pupil	• Size: right, left • Reaction: sluggish, brisk or absent
Eye opening	• To pain, to sound, none or spontaneous
Cry	• Weak, full or high-pitched
Fontanelle (s)	• Sunken, bulging or flat
Sutures	• Over-riding or separated
Seizures	• If present, write a complete description

Table (8-4): Neonatal Reflexes

Reflex	Testing Method	Normal Responses
Babinski (Plantar)	• Stroke one side of neonate's foot upward from the heel and across the ball of the foot	• Neonate hyperextends the toes. Dorsi-flexes the great toe and fans the toes outward
Grasp	• Palmer reflex; place a finger in neonate's palm • Plantar reflex; place a finger against the base of the neonate's toe	• Neonate grasps the finger • Neonate toes curl downward and grasp the finger

Table (8-4): Neonatal Reflexes (Cont'd)

Reflex	Testing Method	Normal Responses
Moro	<ul style="list-style-type: none"> • Suddenly but gently drop the neonate's head backward (relative to the trunk) 	<ul style="list-style-type: none"> • Neonate extends and abducts all extremities bilaterally and symmetrically, then adducts and flexes the extremities
Rooting	<ul style="list-style-type: none"> • Touch a finger to the neonate's cheek or the corner of mouth (the mother's nipple also should trigger this reflex) 	<ul style="list-style-type: none"> • Neonate turns the head toward the stimulus, opens the mouth and searches for the stimulus
Stepping	<ul style="list-style-type: none"> • Hold the neonate in an upright position and touch one foot lightly to a flat surface (such as the bed) 	<ul style="list-style-type: none"> • Neonate makes walking motions with both feet
Sucking	<ul style="list-style-type: none"> • Place a finger in the neonate's mouth (mother's nipple triggers this reflex) 	<ul style="list-style-type: none"> • Neonate sucks on the finger (or nipple) forcefully and rhythmically

Respiratory and chest wall assessment (Table 8-5)

- Breasts of male and female newborns may be swollen, and occasionally engorged, and secreting a white substance (witch's milk); it **should not** be squeezed.
- Prominent xiphoid: a visible, firm lump in the midline of the chest that is frequently observed.
- Perform an assessment every shift or with any change in the clinical condition.

Cardiovascular assessment (Table 8-6)

- Perform an assessment every shift or with any change in clinical condition.
- The apex beat can be palpated in the 3rd or 4th intercostal space just outside the mid-clavicular line.

Table (8-5): Neonatal Respiratory Assessment Parameters

Parameter	Comments
Skin color	Pink, cyanotic, pale, dusky, mottled or jaundiced
Breathing	Unlabored or labored, grunting, nasal flaring or retractions
Chest wall	Deformity, Symmetrical or asymmetrical movement
Breath sounds	Distant, shallow, stridor, wheezing, or diminished, equal or unequal
Apnea/bradycardia /desaturation	Lowest observed HR, color, pulse oximeter reading and duration of episode
Secretion	<ul style="list-style-type: none"> • Amount: scant, moderate or large • Color: white, yellow, clear, green or blood-tinged • Consistency: thick, thin or mucoid
Endotracheal tube	Length at the level of skin

Table (8-6): Neonatal Cardiovascular Assessment Parameters

Parameter	Comment
Precordium	Quiet or active
Skin color	Pink, cyanotic, acrocyanotic, pale, dusky, mottled
Heart sounds	Diminished or easily audible
Rhythm	Normal or describe any arrhythmia
Murmur	Describe, if any
Capillary refill	How many seconds? Where to be elicited?
Peripheral pulses; femoral & brachial	Normal, weak or absent

Gastrointestinal and abdominal assessment (Table 8-7)

- Assess daily or with any change in clinical condition.

Table (8-7): Neonatal Gastrointestinal Assessment Parameters

Parameter	Comment
Abdominal shape	<ul style="list-style-type: none"> • Slightly prominent (normal), distended, scaphoid
Abdominal girth	<ul style="list-style-type: none"> • Record the measurement in cm daily
Umbilical stump	<ul style="list-style-type: none"> • Number of umbilical arteries • Meconium staining • Drying, inflamed, or discharges • Omphalocele
Abdominal wall	<ul style="list-style-type: none"> • Red or discolored, defects • Distended or any visible loops of bowel
Palpation	<ul style="list-style-type: none"> • Soft, tender or rigid, liver (normally is palpated 2 cm below costal margin)
Bowel sounds	Present, absent, hyperactive or hypoactive

Other assessments

e.g., Wound and dressing description, and colostomy output description

CHAPTER 9

Thermoregulation

Normal temperature ranges in neonates:

- Core (rectal) temperature is 36.5-37.5°C
- Axillary temperature may be 0.5-1°C lower
- Skin temperature is 36-36.5°C

Hypothermia

Defined as a core body temperature <36.5°C

Etiology

- Cold environment
- Incorrect care immediately after birth (e.g., inadequate drying, insufficient clothing, separation from the mother, or inadequate warming)
- Diseased and stressed infants

Clinical manifestations

- Measuring the neonate's temperature may not detect early changes of cold stress.
- Initial signs
 - ▶ Feel cold to touch
 - ▶ Weak sucking or inability to suck, lethargy and weak cry
 - ▶ Skin color changes (pallor, cyanosis, mottling or plethora)
 - ▶ Tachypnea and tachycardia
- Later signs
 - ▶ Apnea and bradycardia
 - ▶ Hypoglycemia, metabolic acidosis, respiratory distress and bleeding (e.g., DIC, IVH, and pulmonary hemorrhage)

Hyperthermia

Defined as a core body temperature $>37.5^{\circ}\text{C}$

Etiology

- High environmental temperature (e.g., overbundling of the infant, placing the incubator in sunlight, or a loose skin probe with an incubator or radiant heater on a servo-control mode, or a servo-control temperature set too high)
- Dehydration, infection, or intracranial hemorrhage

Clinical manifestations

- Warm skin; appears flushed or pink initially, and pale later
- Irritability, tachycardia & tachypnea
- Dehydration, intracranial hemorrhage, heat stroke & death

N.B.: If environmental temperature is the cause of hyper-thermia, the temperatures of the trunk and extremities will be the same and the infant appears flushed. In contrast, infants with sepsis have colder extremities than the trunk.

Temperature Assessment

Rectal temperature

- Insert the rectal glass thermometer <3 cm, and hold in place at least 3 min.

Axillary temperature

- Put the thermometer high in the middle of the axilla with the arm held gently but firmly at the infant's side for ≈ 5 min.

Skin temperature

- Secure skin probe to the abdomen (right upper quadrant).

Environmental temperature

- Each room should have a wall thermometer.
- Keep the room temperature between 24 - 26°C .

N.B.: Rectal temperature should not be taken on a routine basis in neonates (risk of vagal stimulation & rectal perforation).

Temperature Control

In the DR & the OR

- Keep the DR & OR warm (24-26°C), free from air currents.
- Dry the neonate immediately and remove any wet towels.
- Encourage direct skin-to-skin contact (SSC) with the mother.
- Use radiant warmers for all neonates who had low Apgar scores, exhibited signs of stress during delivery, and/or whose mothers have had pre and intrapartum risk factors.
- Cover the neonate's head with a cap.

On admission to the NICU

- Undress the neonate except for a diaper and place under the radiant heater.
- Place skin temperature probe flat on the neonate's skin, usually on the abdomen (right hypochondrium).
- Set the servo-temperature at 36.5°C.
- Obtain temperature every 30 min.

During the NICU stay

- Keep incubators away from sunlight.
- Maintain an adequate room temperature & minimize drafts.
- Encourage parents to visit and hold the infant (utilizing SSC).
- Monitor neonate's temperature every 3-4 hrs & maintain core temperature at 36.5-37.5°C.
- Use the portholes as much as possible during care of the neonate, instead of opening the larger door.
- Use radiant warmer during performing medical procedures.

Management of Hypothermia

- Place in isolette with temperature set at 1-1.5°C above body temperature. Re-warm at a rate of 1°C/hr (infants weighing <1,200

gm, those with GA <28 wks and those with temperature <32°C, can be re-warmed more slowly “not to exceed 0.6°C/hr”).

- During re-warming, the skin temperature **should not** be >1°C warmer than the coexisting rectal temperature.
- Avoid using hot water bottles.
- Monitor for apnea and hypotension during re-warming.

Management of Hyperthermia

- Define the cause (the most important initial issue).
- Turn down any heat source and remove excess clothes.

Table (9-1): Neutral Thermal Environmental (NTE) Temperature

Age and Weight	Temperature	
	At Start (°C)	Range (°C)
0-6 hrs		
• Under 1,200 gm	35	34-35.4
• 1,200-1,500 gm	34.1	33.9-34.4
• 1,501-2,500 gm	33.4	32.8-33.8
• Over 2,500 gm	32.9	32-33.8
6-12 hrs		
• Under 1,200 gm	35	34-35.4
• 1,200-1,500 gm	34	33.5-34.4
• 1,501-2,500 gm	33.1	32.2-33.8
• Over 2,500 gm	32.8	31.4-33.8
12-24 hrs		
• Under 1,200 gm	34	34-35.4
• 1,200-1,500 gm	33.8	33.3-34.3
• 1,501-2,500 gm	32.8	31.8-33.8
• Over 2,500 gm	32.4	31-33.7

Table (9-1): NTE Temperature (Cont'd)

Age and Weight	Temperature	
	At Start (°C)	Range (°C)
24-36 hrs		
• Under 1,200 gm	34	34-35
• 1,200-1,500 gm	33.6	33.1-34.2
• 1,501-2,500 gm	32.6	31.6-33.6
• Over 2,500 gm	32.1	30.7-33.5
36-48 hrs		
• Under 1,200 gm	34	34-35
• 1,200-1,500 gm	33.5	33-34.1
• 1,501-2,500 gm	32.5	31.4-33.5
• Over 2,500 gm	31.9	30.5-33.3
48 -72 hrs		
• Under 1,200 gm	34	34-35
• 1,200-1,500 gm	33.5	33-34
• 1,501-2,500 gm	32.3	31.2-33.4
• Over 2,500 gm	31.7	30.1-33.2
72-96 hrs		
• Under 1,200 gm	34	34-35
• 1,200-1,500 gm	33.5	33-34
• 1,501-2,500 gm	32.2	31.1-33.2
• Over 2,500 gm	31.3	29.8-32.8
4-12 days		
• Under 1,500 gm	33.5	33-34
• 1,501-2,500 gm	32.1	31-33.2

Table (9-1): NTE Temperature (Cont'd)

Age and Weight	Temperature	
	At Start (°C)	Range (°C)
• Over 2,500 gm		
▶ 4-5 days	31	29.5-32.6
▶ 5-6 days	30.9	29.4-32.3
▶ 6-8 days	30.6	29-32.2
▶ 8-10 days	30.3	29-31.8
▶ 10-12 days	30.1	29-31.4
12-14 days		
Under 1,500 gm	33.5	32.6-34.0
1,501-2,500 gm	32.1	31-33.2
Over 2,500 gm (and >36 wks' gestation)	29.8	29-30.8
2-3 wks		
Under 1,500gm	33.1	32.2-34
1,501-2,500 gm	31.7	30.5-33
3-4 wks		
Under 1,500 gm	32.6	31.6-33.6
1,501-2,500 gm	31.4	30-32.7
4-5 wks		
Under 1,500 gm	32	31.2-33
1,501-2,500 gm	30.9	29.5-35.2
5-6 wks		
Under 1,500 gm	31.4	30.6-32.3
1,501-2,500 gm	30.4	29-31.8

NTE is the environmental conditions under which the core body temperature is normal with minimal caloric expenditure and oxygen consumption.

CHAPTER 10

Preterm and Low Birth Weight Infants

Classification of Newborns

Based on gestational age (GA)

- Preterm: <37 wks completed wks (259 days)
- Term: 37-41 wks and 6/7 days (260-294 days)
- Post-term: ≥42 wks (295 days)

Based on birth weight

- Normal birth weight: from 2,500-3,999 gm
- Low birth weight (LBW): <2,500 gm
 - ▶ Very low birth weight (VLBW): <1,500 gm
 - ▶ Extremely low birth weight (ELBW): <1,000 gm

N.B.: LBW may be due to prematurity, IUGR, or both

Based on maturity and intrauterine growth

- Small for gestational age (SGA): 2 SD below the mean weight for GA or <10th percentile
- Appropriate for gestational age (AGA): 10th to 90th percentile
- Large for gestational age (LGA): 2 SD above the mean weight for GA or >90th percentile (e.g., IDM's, Beckwith's syndrome, constitutionally large infants, or hydrops fetalis)

Preterm Infant

Problems

Table (10-1): Problems of Prematurity

Respiratory	Perinatal depression, RDS, aspiration, apnea, BPD
Temperature	Hypothermia or hyperthermia
GI - Nutritional	Poor sucking/swallowing reflexes, ↓intestinal motility, delayed gastric emptying, deficient lactase enzymes, ↓stores (Ca, PO ₄), NEC
Hepatic	↓Conjugation & excretion of bilirubin & ↓ vitamin K-dependent clotting factors
Renal	metabolic acidosis, ↓renal elimination of drugs, electrolyte imbalance (hypo/hyponatremia, hyperkalemia or renal glycosuria)
Immunologic	↑Risk of infection
Neurological	Perinatal depression, IVH, PVL
Cardiovascular	Hypotension, PDA, CHF
Hematological	Anemia, ↑bilirubin, DIC, hemorrhagic disease
Metabolic	Hypocalcemia, hypo/hyperglycemia
Ophthalmologic	Retinopathy of prematurity

RDS: respiratory distress syndrome, BPD: bronchopulmonary dysplasia, NEC: necrotizing enterocolitis, PDA: patent ductus arteriosus, CHF: congestive heart failure, IVH: intraventricular hemorrhage, PVL: periventricular leukomalacia, DIC: disseminated intravascular coagulopathy

Investigations

Laboratory

- CBC with differential
- Serial blood glucose measurement
- Serum Na, K, and calcium, as needed
- Serial serum bilirubin measurement, if indicated
- Arterial blood gases, if indicated
- CRP and cultures; to rule out infection

Radiological

- Chest x-ray; with evidence of respiratory distress.
- Cranial ultrasonography; must be done in all preterm infants <32 wks' GA [on or around days 3, 7, 30, 60 (or just before discharge)] and in those ≥32 wks' GA with risk factors (e.g., perinatal asphyxia or pneumothorax) or who present with abnormal neurologic signs to rule out IVH.
- Echocardiography; if PDA is suspected.

Management

A) DR or OR care (Refer to Chapter 2)

B) NICU care

- Thermoregulation: achieve a NTE (**Refer to Chapter 9**).
- Respiratory support: surfactant administration, O₂ therapy, CPAP, or mechanical ventilation (MV); as needed.
- Apnea management
 - ▶ Apply tactile stimulation.
 - ▶ Start theophylline (loading dose 6 mg/kg/IV - followed 8 hrs later by maintenance dose: 2 mg/kg q8 hrs) **or**
 - ▶ Caffeine citrate (loading dose 20 mg/kg PO or IV over 30 min, followed 24 hrs later by maintenance dose 5-8 mg/kg orally or IV q24 hrs)
 - ▶ Start CPAP or MV in recurrent and/or prolonged apnea.
- Fluid and electrolyte therapy
 - ▶ Replace high insensible water loss and large renal losses of fluids and electrolytes to maintain proper hydration and plasma electrolyte levels (**Refer to Chapter 11**).
 - ▶ **Be aware** that excessive fluid intake should be monitored closely (may lead to PDA).
- Glucose homeostasis
 - ▶ Monitor & maintain blood glucose level at 50-125 mg/dl.
 - ▶ GIR 4-10 mg/kg/min is usually sufficient (D7.5W or D5W).

- ▶ If hyperglycemia occurs, use lower glucose concentration; insulin may be required (**Refer to Chapter 13**).
- Calcium homeostasis
 - ▶ Serum total Ca >7 mg/dl does not need correction.
 - ▶ Start on calcium 40-50 mg elemental in the IV fluids; this can be advanced to 70-80 mg elemental/kg/day.
- Nutrition: gavage feeding or parenteral nutrition may be required (**Refer to Chapter 16**).
- Cardiovascular support
 - ▶ Blood pressure
 - Check normal systolic and diastolic BP for GA; low mean arterial pressure may indicate PDA.
 - Assess peripheral perfusion & capillary refill time (should be <2-3 seconds)
 - Early hypotension: give fluid boluses 10-20 ml/kg; start pressor support (initially with dopamine).
 - If an infant is in shock, give whole blood 10 ml/kg or more if obvious blood loss is observed; crystalloid may be used while waiting for blood.
 - Avoid rapid infusions (risk of IVH).
 - ▶ Patent ductus arteriosus
 - Adequate oxygenation, fluid restriction and diuretics
 - Indomethacin may be needed (**Refer to Chapter 31**).
- Anemia: consider erythropoietin therapy in conjunction with adequate iron therapy (**Refer to Chapter 30**).
- Hyperbilirubinemia: monitor serum bilirubin levels, and use phototherapy or perform exchange transfusion, if needed (**Refer to Chapter 17**).
- Infection
 - ▶ Start broad-spectrum antibiotics, if infection is suspected.
 - ▶ Consider anti-staphylococcal antibiotics for VLBW who have undergone multiple procedures or who have remained for a long time in the hospital.

Intrauterine Growth Restriction (IUGR)

Patterns

Symmetric IUGR

- Head circumference, length and weight are all proportionately reduced for GA. It is due to either a congenital infection or a genetic disorder occurring early in pregnancy.

Asymmetric IUGR

- Fetal weight is reduced out of proportion to length and head circumference (head sparing IUGR). It is due to uteroplacental insufficiency or poor maternal nutrition.

Problems

- Fetal death: 5-20 times more than AGA infants
- Hypoxia: perinatal asphyxia, PPHN, meconium aspiration
- Hypothermia, hypoglycemia & polycythemia
- Developmental delay
- Immune depression (neutropenia)
- Bleeding tendency (thrombocytopenia & altered coagulation)

Investigations

- CBC with differential
- Serial blood glucose measurements
- TORCH screening
- Cranial sonar, if indicated
- Chest x-ray, if indicated

Management

A) DR or OR care

- Be prepared for resuscitation to prevent HIE.
- Provide appropriate thermal environment.
- Perform initial assessment for GA.
- Assess for dysmorphic features and congenital anomalies.

- Check serum glucose level.

B) NICU care

- Provide NTE and check temperature every 4 hrs (more frequently, if preterm).
- Initiate early feeding, if possible.
- Check for feeding intolerance.
- Start IV fluids, if feeding is not possible or not tolerated.
- Check Hb level and treat polycythemia, if present.
- Check blood glucose level every 4 hrs during the 1st day of life, then every 8-12 hrs, if stable.

Long Term Follow-Up

- Adequate nutrition
- Developmental assessment
- Maternal counseling for future conception

CHAPTER 11

Fluid and Electrolyte Management

Fluid and Electrolyte Requirements

Fluid requirements

Table (11-1): Fluid Therapy by Infant's Weight and Postnatal Age*

Birth Weight	Glucose Concentration	Fluid Rate (ml/kg/day) [†]		
		Postnatal Age		
		<24 hrs	24-48 hrs	>48 hrs
<1,000 gm	D5W - D7.5W	100-120	120-140	140-190
1,000 - <1,500 gm	D7.5W - D10W	80-100	100-120	120-160
1,500 - <2,500 gm	D10W	60-80	80-100	100-150
≥2,500 gm	D10W	60-80	80-100	90-150

*Infant under humidified incubator.

[†]The volume of fluids given should be estimated based on the infant's clinical status.

- Term infants: depending on the tolerance of the previous day's fluid therapy, estimations of IWL, and clinical status of the infant, increases of 10-20 ml/kg/day may be considered.
- VLBW infants (during the 1st week of life): depending on weight and serum sodium levels, fluid therapy should be managed by increments or decrements of 20-40 ml/kg/day to keep serum sodium at a normal range (135-145 mEq/L).
- ELBW infants (especially <750 gm) may have fluid requirements up to 200 ml/kg/day.
- ↓Daily total fluid intake (-20 ml/kg) for infants on MV.
- ↑Daily total fluid intake (+20 ml/kg) for infants under radiant warmers or phototherapy.

- Give initial GIR (4-6 mg/kg/min in full term & 4-8 mg/kg/min in preterm infants) and adjust to keep the blood glucose level between 50-125 mg/dl.

$$\text{GIR (mg/kg/min)} = \frac{\text{Fluid rate (ml/hr)} \times \text{Glucose concentration}}{6 \times \text{Weight (kg)}}$$

N.B.: Do not infuse a concentration >D12.5W in a peripheral vein.

- By the end of the first week of life, fluid requirements decrease toward 150 ml/kg/day in VLBW infants as the skin becomes more mature.

N.B.: Gastric feeding and any medication that needs dilution before administration (e.g., antibiotic, dopamine); its volume should be subtracted from the total IV fluid intake.

Electrolyte requirements

- For the 1st 24 hrs, supplemental Na⁺ and K⁺ are not required unless ECF expansion is required for shock (**Table 11-2**).
- During the active growth period after the 1st week, the need for K⁺ may increase to 2-3 mEq/kg/day, and the need for Na⁺ & chloride may increase to 3-5 mEq/kg/day.
- Some preterm infants have sodium requirements of as much as 6-8 mEq/kg/day "syndrome of late hyponatremia".

Table (11-2): Initial Electrolytes and Mineral Supplementation

Postnatal Age	Sodium* (mEq/kg/day)	Potassium** (mEq/kg/day)	Calcium Elemental*** (mg/kg/day)
<24 hrs	0	0	45
24-48 hrs	2-3	1-2	45
48-72 hrs	2-3	1-2	45

* Avoid adding sodium for VLBW infants unless serum Na⁺ <135 mEq/L.

Chapter 11: Fluid and Electrolyte Management

- ** **Do not** add potassium until urine output is established and normal renal function is ensured.
- *** Extravasation of calcium-containing solutions can cause tissue necrosis and skin sloughing. The fluid administered must be recorded frequently (every hour) and the site should be observed for any signs of infiltration. Therefore, it is better not to add maintenance calcium to IV solutions infusing in peripheral veins; rather it should be given as an intermittent bolus over 5-15 min with total divided q6 hrs. Maintenance requirements for preterm infant may reach 70-80 mg elemental/kg/day. Consider discontinuation of the maintenance IV calcium, if the infant is tolerating at least 15 ml milk per feed q3 hrs.

Estimating pathologic losses and deficit replacement

- Determine the amount of extra-water required by careful measuring the volume lost.
- Calculate electrolyte losses = the volume of fluid losses × the electrolyte content of the respective body fluids (Table 11-3).

Table (11-3): Electrolyte Content of Body Fluids

Fluid source	Na ⁺ (mmol/L)	K ⁺ (mmol/L)	Cl ⁻ (mmol/L)
Stomach	20-80	5-20	100-150
Small intestine	100-140	5-15	90-120
Bile	120-140	5-15	90-120
Ileostomy	45-135	3-15	20-120
Diarrheal stool	10-90	10-80	10-110

- If the estimation of the composition of the fluid loss is not available, compensate the volume lost by an equal amount of Ringer's solution to which 20 mEq of K⁺ are added to each 500 ml.
- In infants who accumulate fluid and electrolytes in static body fluid compartments "3rd spacing" (e.g., sepsis, NEC & hydrops fetalis), replenish ECF with colloid and crystalloid.

Monitoring of the Fluid and Electrolyte Balance

- Appropriate fluid and electrolyte balance, as reflected by:
 - ▶ Urine output (1-3 ml/kg/hr) & specific gravity (1,005-1,010).

- ▶ Weight loss of $\approx 5\%$ in term infants & $\approx 15\%$ in preterm infants over the first 5-6 days.
- Bedside monitoring of weight gain. Beyond the 1st week of life, infants should gain approximately 20-30 gm/day.
- Laboratory evaluation:
 - ▶ Serum electrolytes (q8-24 hrs, depending on the severity of illness & GA), BUN & creatinine, Hct & blood gases.
 - ▶ Measure serum magnesium in 1st few hrs after birth, if the mother had received magnesium.

N.B.: Assessment of the fluid & electrolyte status may be required initially and as frequently as every 6-8 hrs in ELBW infants.

- ECF depletion is manifest by excessive weight loss, dry oral mucosa, sunken anterior fontanelle, capillary refill time >3 seconds, ↓skin turgor, ↑HR, ↓urine output, ↓BP (with severe hypovolemia), ↑BUN, or metabolic acidosis.

Table (11-4): Assessment of Hydration Status of the Neonate

Parameter	Frequency	Dehydration	Fluid overload
Weight (daily weight loss should not > 1-3% in the 1 st 4-5 days)	daily, twice a day if <1,000 gm	weight loss >3% per day	weight loss <2% per day or weight gain
Skin and fontanelle*	daily, every 8 hrs if <1,000 gm	poor skin turgor & depressed fontanelle	bulging fontanelle
Cardiovascular system	every 4 hrs	tachycardia, delayed capillary refill & hypotension	hepatomegaly, tachycardia and hypertension
Serum sodium**	daily, every 8-12 hrs if <1,000 gm	>145 mEq/L.	<130 mEq/L

Table (11-4): Assessment of Hydration Status of the Neonate (Cont'd)

Parameter	Frequency	Dehydration	Fluid Overload
BUN & creatinine		↑ (may be)	
Hematocrit		↑	↓
<ul style="list-style-type: none"> • Urine volume (1-3 ml/kg/hr) • Specific gravity† (1,005-1,010) • Glycosuria‡ 	with every diaper ^a change	↓urine volume (<1 ml/kg/hr) ↑specific gravity	↑urine volume ↓specific gravity

*Altered skin turgor, a sunken anterior fontanelle, and dry mucous membranes are not sensitive indicators of dehydration in babies.

**Serum sodium is the most useful parameter to follow in VLBW infants during the 1st few days of life.

° BUN & creatinine values may reflect mother's values in the 1st 12-24 hrs of life.

†Urine volume & specific gravity are useful in assessment of fluid status, although reduced function of the immature kidney in the preterm infant may make these parameters less useful.

‡Glycosuria can cause osmotic diuresis & dehydration. If the urine glucose level is 2+, measure the serum glucose and consider adjusting the glucose infusion or the insulin administration.

^a All diapers should be pre-weighed on a gram scale and marked with dry weight. After each stool or void urine the diaper is reweighed; the difference equals the amount of loss.

CHAPTER 12

Water and Electrolyte Imbalance

Hyponatremia

Serum Na level <130 mEq/L (normal level 135-148 mEq/L)

Causes

Table (12-1): Causes of Hyponatremia in a Newborn

Water Overload	Sodium Depletion
<ul style="list-style-type: none"> • Maternal water overload during labor & delivery • Iatrogenic water overload following birth • SIADH (cerebral disease [e.g., birth asphyxia, meningitis] or respiratory disease [e.g., pneumonia, Pneumothorax]) • Indomethacin (↓free water clearance) 	<ul style="list-style-type: none"> • ↑Gastrointestinal losses (vomiting, diarrhea, or nasogastric aspirate) • ↑Fluid removal (drainage of ascites, pleural fluid or CSF) • ↑Renal losses (renal tubular disorders, late hypo-natremia of prematurity, after relief of obstructive uropathy, CAH) • Third space loss (e.g., NEC)

SIADH: syndrome of inappropriate antidiuretic hormone secretion, CSF: cerebrospinal fluid, CAH: congenital adrenal hyperplasia, NEC: necrotizing enterocolitis

Clinical manifestations

- Hypotonia, lethargy and convulsions (with plasma sodium <125 mEq/L, and partly related to the acuteness of the fall)
- Inappropriate ↑weight with iatrogenic water overload in early postnatal life or ↓weight with sodium depletion in later postnatal life
- Features of the underlying disease
- SIADH (suspected by ↓serum Na⁺ & ↓urine output)
 - ▶ Criteria: ↓serum Na⁺, ↑urine Na⁺ loss - urine osmolality > plasma osmolality - normal adrenal & renal function

Management (according to the problem)

- Over hydration
 - ▶ Restrict fluid intake.
 - ▶ Add maintenance Na^+ (2-4 mEq/kg/day) to IV fluids.
 - ▶ If serum $\text{Na}^+ < 120$ mEq/L, correct using replacement formula.
- Renal losses
 - ▶ ↑Maintenance Na^+ (VLBW infants may have sodium requirements of as much as 6-8 mEq/kg/day).
 - ▶ Replace Na^+ loss using replacement formula.
- GIT losses
 - ▶ Replace nasogastric drainage (ml/ml).
 - ▶ Replace Na^+ loss using replacement formula, if the infant is still hyponatremic.
- SIADH
 - ▶ Restrict fluid intake ($\text{IWL} + \frac{1}{3}$ to $\frac{1}{2}$ urine output).
 - ▶ Initiate furosemide (1 mg/kg IV q6 hrs), with Na^+ replacement using hypertonic NaCl 3% (1-3 ml/kg) as an initial dose, if:
 - Serum $\text{Na}^+ < 120$ mEq/L.
 - Neurologic signs such as seizures develop.
 - ▶ Once serum $\text{Na}^+ > 120$ mEq/L & neurologic signs abort, fluid restriction alone can be utilized.

N.B.: Rapid correction of hyponatremia → pontine myelinolysis.

Sodium replacement formula

Total Na^+ replacement =

$$\text{Desired } \text{Na}^+ (\text{mEq}) - \text{Actual } \text{Na}^+ (\text{mEq}) \times \text{Weight (kg)} \times 0.6$$

- Give half replacement (over at least 6-8 hrs) in the maintenance IV fluid.
- Check serum Na^+ after the 1st replacement; if additional Na^+ is needed, give the 2nd half over the next 16 hrs.
- Correct by using hypertonic NaCl 3% (1 mEq in 2 ml).

Hypernatremia

Serum sodium level >150 mEq/L

Causes

Water depletion

- ↓Free water intake (as in lactation failure)
- ↑Transepidermal water loss (e.g., skin sloughing)
- ↑Renal losses (e.g., glycosuria & diabetes insipidus)

Sodium overload

- Sodium-containing solution administration (NaHCO₃ bolus infusion and sodium-containing medications).

N.B.: FFP, blood & human albumin contain sodium, and can contribute to hypernatremia when given repeatedly to very premature infants.

Clinical manifestations

- Hypertonicity & convulsions.
- A full fontanelle may suggest hypernatremic dehydration.
- Diagnosis may be delayed as signs of hypovolemia and decreased skin turgor occur late.
- Severe hypernatremia may lead to permanent CNS damage.

Management (according to problem)

Hypernatremia with deficient ECF volume

- ↑Free water administration.
- Use D5W/0.3-0.45% saline solution IV in volumes equal to the calculated fluid deficit, given over 48-72 hrs.
- Monitor weight, serum electrolytes, and urine volume & specific gravity, adjust fluid administration accordingly.
- Once adequate urine output is noted, add potassium.

Hypernatremia with ECF volume excess

- Restrict Na⁺ administration.

N.B.1: High serum sodium level indicates that the infant requires fluids till proved otherwise.

N.B.2: Rapid fall in serum sodium → cerebral edema; reduce serum Na^+ level no faster than 0.5-1 mEq/L/hr.

N.B.3: Consider peritoneal dialysis in extreme hypernatremia.

Hypokalemia

Serum potassium level <3.5 mEq/L (normal level 3.5-5.5 mEq/L)

Causes

- Chronic diuretic or amphotericin-B use
- Renal tubular defects
- Nasogastric drainage, or ileostomy drainage

Clinical manifestations

- Asymptomatic, or may be weakness, paralysis, lethargy, ileus & arrhythmia
- ECG changes: flat T wave, prolonged QT interval, U wave

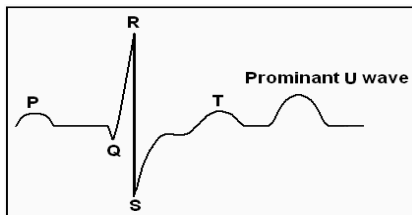


Figure (12-1): ECG changes in hypokalemia

Management

- Treat the cause.
- When significant, treat by slow potassium replacement, either PO or IV (1 mEq/kg KCl → ↑serum K^+ 1 mEq/L), with dose adjustment based on serum K^+ level.
 - ▶ Oral therapy: 0.5-1 mEq/kg/day divided and given with feedings (small, more frequent aliquots preferred)
 - ▶ Constant IV infusion (2-3 mEq/kg/day)

- ▶ IV therapy: KCl (1 mEq/kg) over a minimum of 4 hrs. For emergency treatment of symptomatic hypokalemia (arrhythmias), KCl (0.5-1 mEq/kg IV) may be given over 1 hr, and then reassess (maximum infusion rate is 1 mEq/kg/hr).
- ▶ **Maximum concentration** of K^+ : 40 mEq/L for peripheral venous infusion & 80 mEq/L for central venous infusion.

N.B.: - Rapid administration of potassium is not recommended as life-threatening cardiac arrhythmias may occur.

- Do not give potassium to an infant who is not voiding.

Hyperkalemia

Serum potassium level >6 mEq/L in a non-hemolyzed specimen

Causes

- ↑Potassium administration
- ↓Potassium clearance (e.g., renal failure & CAH)
- ↑Potassium release (e.g., IVH, cephalhematoma, intravascular hemolysis, bowel infarction & hypothermia)
- Extracellular shift of potassium as severe acidosis

Clinical manifestations

- It may be asymptomatic or may result in arrhythmias and cardiovascular instability.
- ECG changes: peaked T waves, flattened P waves, ↑PR interval, widening of the QRS, bradycardia, tachycardia, SVT, ventricular tachycardia, and ventricular fibrillation



Figure (12-2): ECG changes in hyperkalemia

Management

- Discontinue all exogenous sources of potassium.
- Stabilize the conducting system, by:
 - ▶ Calcium gluconate 10% (1-2 ml/kg) IV over 1 hr
 - ▶ Antiarrhythmic agents e.g. lidocaine and bretylium
- Dilution and intracellular shifting of K^+
 - ▶ $NaHCO_3$ 1-2 mEq/kg (slowly, at least over 30 min). Avoid rapid infusion (may lead to IVH especially in infants <34 wks' gestation & younger than 3 days).
 - ▶ β_2 agonists (e.g., albuterol), via nebulizer.
 - ▶ Human regular insulin (a bolus of 0.05 unit/kg), with D10W (2 ml/kg), followed by a continuous infusion of insulin 10 units/100 ml, at a rate of 1 ml/kg/hr, with 2-4 ml/kg/hr D10W. Monitor for hypoglycemia.
- Enhanced K excretion
 - ▶ Furosemide 1 mg/kg/dose (if adequate renal function).
 - ▶ Peritoneal dialysis or double volume exchange can. Use fresh whole blood (<24 hrs).

N.B.: Peritoneal dialysis may be technically impossible in VLBW infants and in NEC.

Hypocalcemia

Total serum calcium <7 mg/dl or ionized calcium <4 mg/dl (<1 mmol/L)

Causes

- Early onset hypocalcemia occurs within the first 3 days of life, and is associated with IDM's, asphyxia & prematurity.
- Late onset hypocalcemia develops after the 1st wk of life & usually has a specific cause (e.g., high phosphate intake, malabsorption).

Clinical manifestations

- Often asymptomatic but may show jitteriness, twitches, apnea, seizures and abnormalities in cardiac function.

Management

- Prevented by infusion of 20-45 mg/kg/day (up to 70-80 mg/kg/day for preterm infant) elemental calcium in IV fluids.
- If asymptomatic and total serum Ca^{+2} >6.5 mg/dl or an ionized Ca^{+2} >0.8-0.9 mmol/L → observe closely.
- If biochemical abnormality persists (total serum Ca^{+2} <6.5 mg/dl or ionized Ca^{+2} <0.8-0.9 mmol/L) → give additional elemental calcium IV (10-20 mg/Kg for 4-6 hrs).
- If active seizures → give calcium therapy (10-20 mg/Kg elemental calcium by IV infusion over 10-15 min).
- Care should be taken in administering the IV calcium
 - ▶ Monitor HR; discontinue infusion if <100/min.
 - ▶ Infants who are on digoxin should receive calcium only by constant infusion.
 - ▶ Check the IV site before & during administration.

Oliguria

Defined as a urine output of <1 ml/kg/hr.

Etiology

Table (12-2): Etiology of Oliguria in Neonates

Prerenal Failure	Intrinsic Renal Failure	Postrenal Failure
<ul style="list-style-type: none"> • Shock, or dehydration • CHF 	<ul style="list-style-type: none"> • ATN (prolonged ischemia, drugs, toxins) • DIC • Renal vein thrombosis • Malformations (polycystic, agenesis, dysplastic) 	<ul style="list-style-type: none"> • PUV • Neuropathic bladder • Prune-belly syndrome

CHF: Congestive heart failure, ATN: acute tubular necrosis, DIC: disseminated intravascular coagulopathy, PUV: posterior urethral valve

Diagnosis

History

- Maternal diabetes (renal vein thrombosis)

Chapter 12: Water and Electrolyte Imbalance

- Birth asphyxia (ATN)
- Oligohydramnios (Potter syndrome)
- Force of urinary stream (PUV)
- Nephrotoxic drugs (e.g., aminoglycoside, indomethacin)

Physical examination

- Signs of ECF volume depletion (poor skin turgor, depressed fontanelles, delayed capillary refill time, ↑HR & ↓BP)
- Evidence of cardiac disease
- Signs of acute renal failure (volume overload; as edema, CHF, hepatomegaly, and pulmonary edema)
- Abdominal masses, ascites, or congenital anomalies.
- Suprapubic bladder mass.
- Chest x ray for evaluation of the size of the heart.

N.B.: If a urinary catheter is in place, confirm the absence of obstruction or leakage around the catheter.

Laboratory investigations

- Urine analysis
- BUN, plasma creatinine & BUN/creatinine ratio
- Fractional excretion of sodium (FE-Na):

$$\text{FE-Na} = \frac{\text{Urine Na} \times \text{Plasma creatinine}}{\text{Plasma Na} \times \text{Urine creatinine}} \times 100$$

- ▶ Level of <1% suggests prerenal failure.
 - ▶ Level of 2.5% suggests acute renal failure.
 - ▶ Premature infants <32 wks' gestation frequently show elevated values of FE-Na (>2.5%).
- GFR

$$\text{GFR (ml/min/1.73 m}^2\text{)} = k \times \text{Length (cm)} / \text{Plasma creatinine (mg/dl)}$$

[k = 0.33 (in preterm infants) and 0.45 (in full-term infants)]

Fluid challenge test (to rule out hypovolemia)

- Give NS (20 ml/kg), as 2 infusions at 10 ml/kg/hr, after exclusion of CHF; dopamine (1-5 µg/kg/min) may be given.
 - ▶ If no response and the BP is adequate, and the cardiac size is adequate in the chest x-ray film (cardiothoracic ratio = 0.6), induce diuresis with furosemide 2 mg/kg IV.
 - ▶ If no response, do an abdominal ultrasonography to define renal, urethral and bladder anatomy.

Central venous pressure (CVP)

- UVC may be used for CVP monitoring (it should be placed at the level of the right atrium [0.5-1 cm above the diaphragm] with placement confirmed by chest x-ray film).
- Normal levels: between 4-6 mmHg (the range is 2-8 mmHg).
- ↓CVP: hypovolemia & inadequate preload.
- ↑CVP: fluid/volume overload (e.g., CHF) and ↑intrathoracic pressure (e.g., pneumothorax).

Management

- Prerenal oliguria: increase cardiac output.
- Postrenal obstruction: consult urologist.
- Intrinsic renal failure:
 - ▶ Daily weight, input, output, BUN, creatinine & electrolytes.
 - ▶ Restrict fluid intake to IWL ($500 \text{ ml/m}^2/\text{day}$, or 30 ml/kg/day) + urine output + other measured losses.
 - ▶ Correct metabolic acidosis, only if pH < 7.2 (unless PPHN).
 - ▶ Withhold K^+ intake unless hypokalemia develops.
 - ▶ Discontinue nephrotoxic drugs, choose drugs with minimal or no renal toxicity, adjust dosage and interval of administration of drugs with renal elimination according to the degree of dysfunction & monitor serum drug levels.
 - ▶ Peritoneal or hemodialysis may be indicated.

CHAPTER 13

Disorders of Glucose Homeostasis

Hypoglycemia

Etiology

Serum glucose level <45 mg/dl in term or preterm infants

Table (13-1): Causes of Hypoglycemia in Neonates

↓Glucose Stores and ↓ Production	↑Glucose Utilization (Hyperinsulinism)	↑Glucose Utilization and/or ↓Production
<ul style="list-style-type: none"> • IUGR or SGA • Preterm or post-term neonates • ↓Caloric intake • Delayed feeding 	<ul style="list-style-type: none"> • IDMs or LGA infants • Erythroblastosis fetalis • Abrupt cessation of high glucose intake • Beckwith-Weidemann syndrome • Islet cell hyperplasia • Insulin producing tumors • After exchange transfusion • Maternal drugs (intrapartum glucose infusion) 	<ul style="list-style-type: none"> • Perinatal stress (hypothermia, sepsis, asphyxia, respiratory distress, shock) • Polycythemia • Maternal drugs (β-blockers, steroids) • Endocrine deficiency (adrenal hemorrhage, CAH, hypothyroidism) • IEMs (galactosemia, GSD, tyrosinemia) • Congenital heart diseases

IUGR: intrauterine growth restriction, SGA: small for gestational age, IDMs: infants of diabetic mothers, LGA: large for gestational age, CAH: congenital adrenal hyperplasia, IEMs: inborn errors of metabolism, GSD: glycogen storage disease

Clinical Manifestations

- Signs are **non-specific** and can be similar to signs of many other problems, some infants may be asymptomatic.

- Serum glucose levels should always be evaluated and treated in high risk infants in which hypoglycemia is anticipated or when there are any of the following signs: jitteriness, tremors, irritability, seizures, coma, apnea, cyanosis, lethargy and poor feeding, weak or high-pitched cry, hypothermia & respiratory distress.

N.B.: Clinical signs of hypoglycemia should be alleviated with concomitant correction of plasma glucose levels.

Management

- Screen by dextrostix. If hypoglycemia is observed, confirm the result by a serum laboratory value.
- Management includes anticipation of neonates at risk, correction, and investigation and treatment of the cause.

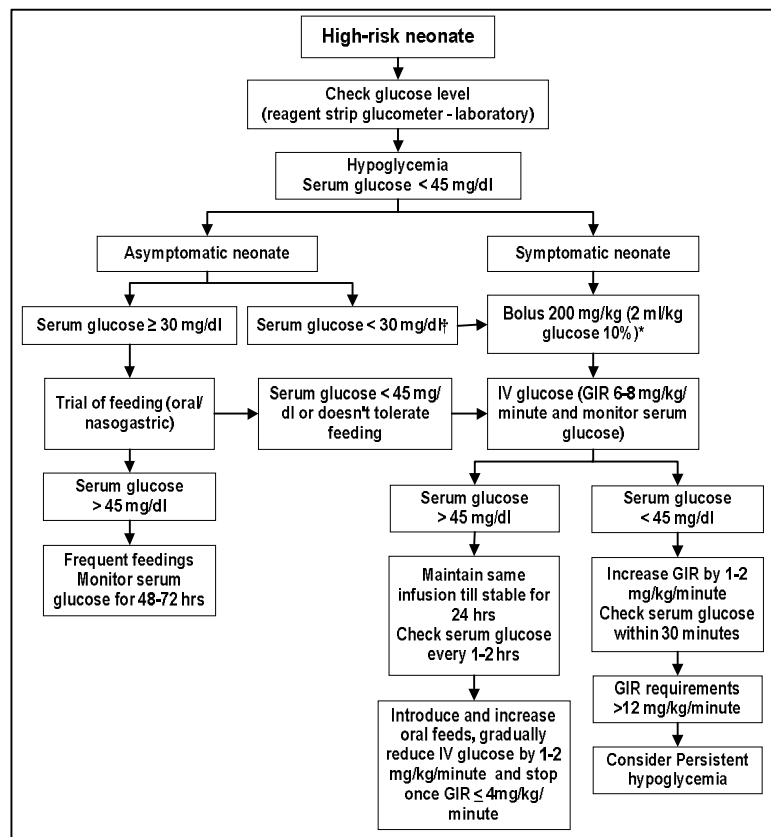
Prevention

- At birth, dry the baby, avoid hypothermia & encourage SSC.
- Encourage early enteral feeding (within 1 hr of age) and frequently thereafter (at least 8 feeds/day).
- Perform serial blood glucose monitoring in infants at risk of hypoglycemia, starting from the 1st 1-2 hrs of life & do not allow them to wait for >3 hrs between feedings. Monitor blood glucose values until full feedings are taken and 3 normal pre-feeding readings >45 mg/dl.
- Initiate tube-feeding with EBM or formula in infants who are not able to suck adequately. Feed hourly to start off, with increasing the interval between feeds, if blood glucose remains >45 mg/dl and the infant tolerates feedings.
- Initiate IV D10W, if the infant is unable to tolerate nipple or tube feedings, with blood glucose monitoring.

N.B.: Glucose level in the whole blood is 10-15% lower than in the plasma

Treatment (Figure 13-1)

N.B.: Persistent hypoglycemia necessitates pediatric endocrinology consultation. Meanwhile, continue infusion with a GIR adequate to maintain blood glucose >45 mg/dl. A central line could be inserted to allow infusing glucose solution >12.5%.



* Additional bolus infusion may be needed. †Feeding could be started while searching for an IV line - GIR; Glucose infusion rate

Figure (13-1): Management of neonatal hypoglycemia

Hyperglycemia

Whole blood glucose >125 mg/dl or plasma glucose >145 mg/dl

Etiology

Exogenous parenteral glucose, drugs (e.g., steroids, theophylline), ELBW infants, sepsis, stress & neonatal diabetes mellitus

Treatment

- ↓GIR (4-6 mg/kg/min); **avoid solutions < glucose 5%.**
- Start feeding, if general condition of the infant allows.
- Prepare the used drugs in normal saline or distilled water instead of glucose solutions.
- Initiate continuous insulin infusion:
 - ▶ If blood glucose >200-250 mg/dl despite lowering GIR.
 - ▶ Add 15 units' regular human insulin to 150 ml D10W or NS (final concentration = 0.1 unit/ml). Flush the IV tubing with a minimum of 25 ml of this insulin solution.
 - ▶ Rate: 0.01-0.2 unit/kg/hr (= 0.1-2 ml/kg/hr)
 - ▶ Check blood glucose every 30 min until stable and adjust infusion rate:
 - If blood glucose remains >180 mg/dl: titrate in increments of 0.01 unit/kg/hr.
 - If hypoglycemia occurs: discontinue insulin infusion & give D10W IV bolus of (2 ml/kg × 1 dose).
 - ▶ Monitor for rebound hyperglycemia.

CHAPTER 14

Infant of a Diabetic Mother (IDM)

Problems

Metabolic

- Hypoglycemia: the onset is frequently within 1-2 hrs of age.
- Hypocalcemia: it becomes apparent 48-72 hrs after birth.
- Hypomagnesemia: serum magnesium level <1.5 mg/dl

Morphological and functional

- Birth injuries: fracture clavicle, Erb's or phrenic nerve palsies.
- Congenital malformations: cardiac (e.g., TGA & VSD), neurologic (e.g., open meningocele), skeletal (e.g., caudal agenesis syndrome), renal (e.g., agenesis) & GIT (e.g., small left colon syndrome or situs inversus).
- Perinatal asphyxia
- Cardiorespiratory: RDS, TTN & hypertrophic cardiomyopathy
- Polycythemia & hyperviscosity
- Hyperbilirubinemia
- Renal venous thrombosis

Clinical Manifestations

- IDM may be LGA or SGA.
- Puffy and plethoric face.
- Tremors and hyperexcitability
- IDM may show hypoglycemia, lethargy with poor feeding, apnea, or jitteriness (first 6-12 hrs after birth), respiratory distress or heart failure, and congenital anomalies

Diagnosis and Work-up

Laboratory studies

- Glucose level (blood/serum): check by dextrostix at delivery and at 1, 2, 3, 6, 12, 24, 36, and 48 hrs of age; readings <45 mg/dl should be verified by serum glucose measurements.
- Serum calcium level: check on admission and repeat if infant is jittery or appears sick. If low, obtain serum magnesium level.
- Hematocrit: check at 1 and 24 hrs of age.
- Serum bilirubin levels: as indicated by physical examination.
- Other tests: blood gas analysis, CBC with differential, and cultures, as clinically indicated.

Radiological studies

- If cardiac, respiratory, or skeletal problems are evident.
- Echocardiography, if cardiomyopathy or cardiac anomalies are suspected.

Management

Hypoglycemia (Figure 14-1 and Chapter 13)

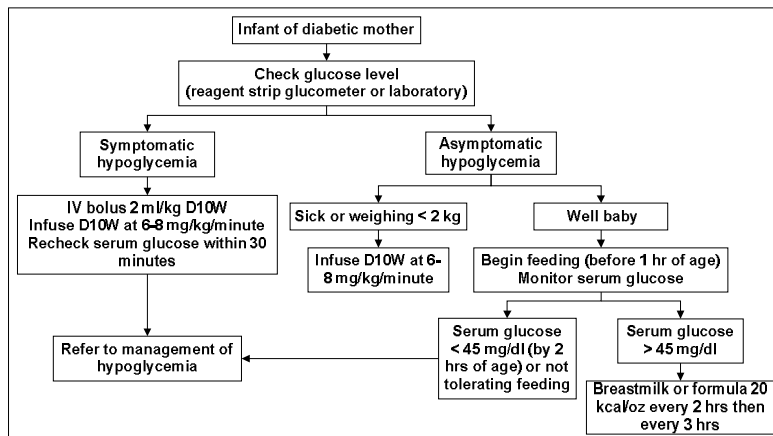


Figure (14-1): Approach for management of hypoglycemia in IDM

Hypocalcemia

- Calcium gluconate 10%: initial 1-2 ml/kg/dose IV, slowly over 10 min with HR monitoring, then maintenance dose (2-8 ml/kg/day) by continuous IV infusion.

Hypomagnesemia

- Magnesium sulfate (MgSO_4 - 50% solution): 0.05-0.1 ml/kg (0.2-0.4 mEq/kg), slow IV infusion over 30 min, repeated doses may be required q6-12 hrs until serum magnesium level is normal or symptoms resolve.
- Start concomitant oral magnesium, if the infant is tolerating oral fluids (MgSO_4 50% solution 0.2 ml/kg/day).

N.B.: if MgSO_4 (50% solution) is not available, use MgSO_4 10% solution in a dose of 0.5-1 ml/kg.

Cardiorespiratory support

- Oxygen therapy, CPAP, or MV, as needed
- Cardiomyopathy: administer oxygen, use furosemide cautiously, and in severe cases, give propranolol. **Inotropic agents are contraindicated.**

Hyperbilirubinemia

- Monitor serum bilirubin levels.
- Phototherapy and exchange transfusion, when needed.

Polycythemia (Refer to Chapter 30)

Macrosomia and birth injuries (Refer to Chapter 28)

CHAPTER 15

Breastfeeding

Breastfeeding of the Well Newborn

- Encourage early breastfeeding
 - ▶ Encourage immediate skin to skin contact (SSC) in all newborns not requiring resuscitation.
 - ▶ Keep the infant in the mother's room (rooming in), or better in the same bed (co-bedding).
- Avoid giving the infant prelacteals (e.g., glucose, anise).
- Correct positioning and latching-on
 - ▶ Proper positioning (**Figure 15-1**)
 - Mother needs to be relaxed and comfortable.
 - Infant should be straight, supported by mother's arm, and infant's body should be close to and facing mother's body.
 - ▶ Breast support "C-hold" is not mandatory but it is preferable in the 1st weeks of life or if large breast size.
 - ▶ Breastfeeding positions for twins (**Figure 15-2**).

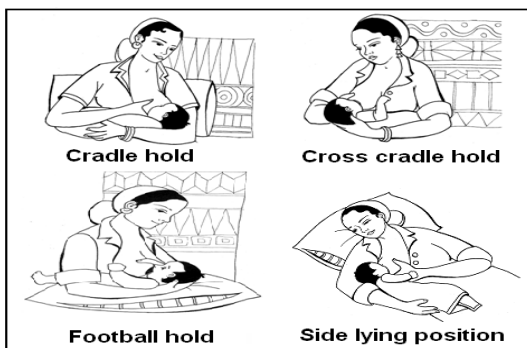


Figure (15-1): Commonly used breastfeeding positions

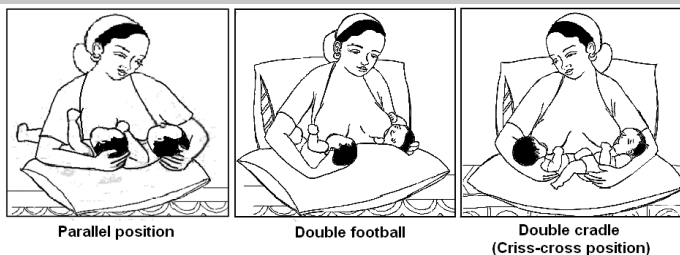


Figure (15-2): Breastfeeding of twins

► **Proper Latching**

- Adjust the infant to face the breast with his nose opposite the nipple, mother should touch infant's nose or upper lip with her nipple till the infant opens his mouth widely, then rapidly direct the infant to the breast.
- Good attachment; all these signs should be present:
 1. Infant's mouth is wide open.
 2. Infant's chin is touching the breast.
 3. Infant's nose is lightly resting on breast.
 4. Infant's upper and lower lips turned outward.
 5. Infant's cheeks should look full.
 6. More areola is visible above the infant's mouth than below the mouth.
 7. The infant suckles effectively with slow deep sucks, sometimes pausing.

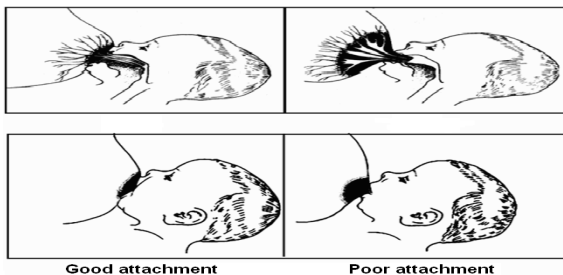


Figure (15-3): Proper latching

- Feeding on demand (no scheduling). When infants are hungry, they express the following feeding cues:
 - ▶ Turning the head and opening the mouth with searching movements (rooting)
 - ▶ Mouthing movements of lips and tongue
 - ▶ Bringing hand to mouth, sucking on a fist or fingers
 - ▶ Moving legs or arms
 - ▶ Head bobbing
 - ▶ Crying (late hunger cue)
- Infant should empty the breast before switching to the other
- Encourage night feeds
- Avoid bottles and pacifiers
- Avoid supplements (e.g., water, herbals) before 6 months

Assessment of the Breast Milk Supply

- Adequate weight gain: infant loses 5-7% of his/her birth weight after delivery, then weight is regained within 2 wks; the average newborn weight gain is 25-35 gm/day
- Wetting 6 heavy diapers every 24 hrs
- Expelling 2 or more bowel movements every 24 hrs.

Milk Expression

Frequency of milk expression

- Mother should begin pumping the breasts within 6 hrs of infant's birth, if she does not nurse immediately postpartum.
- At least 8 good nursing and/or pumping sessions/24 hrs.
- Mother should pump at least once during the night, and avoid going >5-6 hrs without pumping.
- Mother should empty the breast as thoroughly as possible at each session (even if the infant will not take it all). She should keep pumping the breast gently for 2-5 min after the last drops of milk.

Stimulation of milk let-down

- Mother should sit comfortably and relax.

Chapter 15: Breastfeeding

- SSC before or during milk expression.
- Mother can use warm compresses or warm shower.
- Mother should be informed to:
 - ▶ Stimulate the nipples by gentle rubbing and pulling.
 - ▶ Gently massage, stroke, and shake the breast.
 - ▶ Interrupt expression several times to massage the breasts.
- Infant may be nursing on the other side. If he is not present, the mother can put his picture, smell his clothes or think of him.
- Galactagogues: fenugreek, fennel, metoclopramide (30-45 mg/day in 3-4 divided doses for 7-14 days then taper over 5-7 days) or domperidone (10-20 mg 3-4 times/days for 3-8 wks).

Methods of milk expression

Hand expression

Inform the mother to:

- Wash hands thoroughly.
- Hold the container under the nipple and areola.
- Position the thumb & 1st 2 fingers 1-1 ½ inches behind the nipple, then place the thumb above and the other fingers below, in 12 & 6 O'clock positions.
- Push the breast up & backwards straight into the chest wall.
- Roll the thumb and fingers forwards. The mother should slide fingers & skin as one unit over the underlying ducts.
- Rotate the thumb and fingers position to milk the other ducts.

Mechanical expression (breast pumps)

They should be sterilized once daily in boiling water then washed with soap and hot water for subsequent use.

- Syringe breast pumps:
 - ▶ Cut the end of a 50 ml syringe near the nozzle with a sharp knife, then remove the piston from the blunt end and reintroduce through the newly cut sharp end.
 - ▶ Mother puts the blunt end over her areola and does rapid to & fro movements with the piston.

- Battery operated, electric breast pumps
- Rubber bulb (bicycle horn) is not recommended.

Transporting the Expressed Breast Milk (EBM)

Fresh, refrigerated or frozen milk can be packed in an insulated cooler in ice or blue ice (for up to 24 hrs). If the frozen milk is thawed during transportation it should be used or discarded but not refrozen.

Storage of EBM

Glass container is the best choice for freezing milk. Hard, clear plastic container is the 2nd choice.

Table (15-1): Storage Guidelines of the Expressed Breast Milk

Freshly Expressed Milk: refrigerate, as soon as possible, if not using within 4 hrs	
• Room temperature (24-26°C)	4 hrs
Refrigerated Milk: store at back; do not store in-door	
• Refrigerator (fresh milk)	48 hrs
• Refrigerator (thawed milk)	24 hrs
Frozen Milk: store at back; do not store in door; do not refreeze	
• Freezer compartment inside refrigerator door	Not recommended
• Freezer compartment with separate door	3 months
• Deep freeze (not attached to refrigerator)	6 months

Precautions

- Store in amounts equal to what the infant will take in one feed.
- Label each container with name, date, time, and amount.
- Refrigerate or freeze immediately after expression. Milk in the refrigerator may be frozen within 48 hrs.
- Serve EBM to the infant warm by putting it under running warm water or in a bowl of warm water.
- Never use a microwave oven to defrost or warm milk.
- The fresher the better; however colostrums should be provided to the infant whenever the infant starts feeds.

Chapter 15: Breastfeeding

- Gently swirl EBM (don't shake) before offering to the infant.
- Thaw milk by slow defrosting of the total amount overnight in the refrigerator. Once thawed, it should be used within 24 hrs.
- Discard the unused warmed milk.

Methods of giving EBM

Nasogastric tube

If infusion pumps are used, the syringe should be tilted upwards at 25-45° angles.

Cup feeding

It can be initiated when the infant starts swallowing, and should not be given to any newborn that is likely to aspirate.

Procedure

- Wrap and support the infant in an upright sitting position.
- Fill the 30 ml medicine cup at least ½ full with EBM.
- Place the rim of the cup at the outer corners of the upper lip, resting gently on the lower lip with the tongue inside.
- Tip the cup, so the milk is just touching the infant's lips. Do not pour the milk into the infant's mouth. The infant usually laps the milk, or may sip it (simulating a drinking cat).
- Allow time for the infant to swallow.
- Leave the cup in position during the feed (i.e. while the infant rests, do not move the cup from this position).
- Stop to burp the infant from time to time.

Dropper/syringe

- Make sure that it is directed to the side of the mouth, not backwards in the mouth to avoid choking.
- Push 0.25-0.5 ml and wait till the infant swallows.
- Burp the infant when he refuses to swallow.
- Use one syringe for each feed.

N.B.: Bottle feeding should be avoided.

CHAPTER 16**Nutrition of At-Risk Infant****Enteral Nutrition****When to Start Feeding?**

- Start feeding as soon as it is medically possible.
- Evaluate the ability to feed the baby daily.
- Generally, for preterm infants, enteral feeding is started in the first 3 days of life with the objective of reaching full enteral feeding in 2-3 wks, and for stable, larger infant (>1,500 gm), the first feed may be given within 24 hrs of life.

Contraindications for Early Feeding

- Significant hypoxic/asphyx event or acidosis
- Severe hypotension and hemodynamic instability with or without sepsis
- Severe respiratory distress with sustained RR >80/min
- Suspected or confirmed NEC
- Intestinal obstruction/perforation or ileus
- Symptomatic PDA
- Indomethacin treatment for PDA (controversial)

Indications to Start Feeding

- Presence of bowel sounds
- Lack of abdominal distension
- Stable blood pressure
- Stable electrolytes
- Stable respiratory status

Initiating and Advancing Enteral Feeds

A) Trophic feeding (minimal enteral nutrition “MEN”)

Indications

- ELBW infants (birth weight <1,000 gm)
- Infants recovering from NEC
- Infants who have been NPO for an extended period of time

N.B.: MV or UAC (per se) is not a contraindication for MEN.

Strategy

- Ensure hemodynamic stability (usually by day 2-3 of life).
- Use colostrum/breast milk or full strength term or preterm formulas (20 kcal/oz); EBM is preferred.
- Continue MEN until the infant becomes clinically stable enough for feeding advancement, and then proceed to nutritive enteral feedings slowly, with assessment of feeding tolerance.

Table (16-1): Milk Volumes Used for Minimal Enteral Nutrition

Day of Life # 1-2	NPO
Day of Life # 3-4	1 ml every 6 hrs
Day of Life # 5-6	1 ml every 4 hrs
Thereafter	Advance slowly to reach 10-20 ml/kg/day divided into equal aliquots every 3-6 hrs

B) Standard feeding advancement (nutritive feeding)

Energy

- Caloric requirements for healthy term infants \approx 100-120 kcal/kg /day & for preterm infants \approx 120-130 kcal/kg /day.
- Infants with severe and/or prolonged illness (e.g., sepsis, BPD) have energy requirements up to 130-150 kcal/kg/day.

Strategy

- Generally, if bolus feedings are tolerated, feed infants weighing <1,200 gm every 2 hrs and those weighing more every 3 hrs.

- Volume goal = 140-160 ml/kg/day; as enteral volumes are increased, the IV fluid rate is reduced accordingly.
- Weight-specific guidelines are based on birth weight and GA (Table 16-2).

Table (16-2): Weight-Specific Guidelines for Enteral Feeding

Weight (gm)	GA	Volume	Type
1,200	<30 wks	1-2 ml/kg q2hrs advance by 10-20 ml/kg/ day	EBM, term or preterm formulas (20 kcal/oz) Once full feedings are tolerated, consider preterm formulas (24 kcal/oz), or adding HMF to EBM
1,200-1,500	<32 wks	1-2 ml/kg q3 hrs, advance by 10-20 ml/kg/ day	EBM, term or preterm formulas (20 kcal/oz) Once full feedings are tolerated, consider preterm formulas (24 kcal/oz) or adding HMF to EBM
1,500-2,000	32-36 wks	2.5-5 ml/kg q3 hrs, advance by 10-20 ml/ kg/day, as tolerated	EBM or preterm formulas
2,000-2,500	>36 wks	5 ml/kg q3 hrs, advance by 10-20 ml/kg/day as tolerated	EBM or term formula

GA: gestational age, HMF: human milk fortifiers, EBM: expressed breast milk

Another suggested enteral feeding strategy for stable, growing preterm infants (Table 16-3); this should be individualized based on the infant's clinical status/severity.

Table (16-3): Suggested Guidelines for Feeding Preterm Infants

Day of Life	Type of Milk	Volume (ml/kg)	Frequency (hrs)	Increases
Body Weight <1,000 gm				
3-9	EBM, term, or PT formula* (20 kcal/oz)	1-2	6-12	None
10-16	EBM, term, or PT formula* (20 kcal/oz)	2	2	15 ml/kg/day
17-19	EBM, term, or PT formula* (20 kcal/oz)	8-9	2	20 ml/kg/day
20-21	Fortified EBM* or PT formula (24 kcal/oz)	12-13	2	↑↑ weight
22-23	Fortified EBM* or PT formula (24 kcal/oz)	12-13	2	↑↑ weight
Body Weight 1,001-1,200 gm				
2-6	EBM, term, or PT formula* (20 kcal/oz)	3-5	6	None
7-11	EBM, term, or PT formula* (20 kcal/oz)	2	2	20 ml/kg/day
12-14	EBM, term, or PT formula (20 kcal/oz)	8-9	2	20 ml/kg/day
15	Fortified EBM* or PT formula (24 kcal/oz)	12-13	2	↑↑ weight
17	Fortified EBM* or PT formula (24 kcal/oz)	12-13	2	↑↑ weight
Body Weight 1,201-1,500 gm				
2-6	EBM, term, or PT formula* (20 kcal/oz)	3-5	6	None
7-11	EBM, term, or PT formula* (20 kcal/oz)	2	3	20 ml/kg/day
12-14	EBM, term, or PT formula* (20 kcal/oz)	8-9	3	20 ml/kg/day
15	EBM, term, or PT formula* (20 kcal/oz)	12-13	3	↑↑ weight
17	Fortified EBM* or PT formula (24 kcal/oz)	12-13	3	↑↑ weight
Body Weight 1,501-2,000 gm				
1-3	EBM, term, or PT formula* (20 kcal/oz)	5	6	None
4-5	EBM, term, or PT formula* (20 kcal/oz)	3	3	None
6-9	EBM, term, or PT formula* (20 kcal/oz)	3	3	20 ml/kg/day
10-12	Fortified EBM* or PT formula (24 kcal/oz)	12-14	3	20 ml/kg/day
13	Fortified EBM* or PT formula (24 kcal/oz)	18-20	3	↑↑ weight

*Means to be used if available, EBM: Expressed breast milk, PT: Preterm formula

Composition of Enteral Feedings

Breast milk

- Use HMF in preterm infants with birth weights <1,500 gm & consider HMF in those with birth weights <2,000 gm.

- Start adding HMF once infants are tolerating 100 ml/kg/day of breast milk and continue for up to the time of discharge or at a weight of 2,000 gm.

Formulas

- Term formulas (20 kcal/oz)
- Preterm formulas (20 kcal/oz and 24 kcal/oz)
 - ▶ Indicated in preterm infants <1,800-2,000 gm.
 - ▶ Start with preterm formula (20 kcal/oz) and advance to preterm formula (24 cal/oz), as tolerated, at 100 ml/kg of volume. This volume is then maintained for 24 hrs before the advanced schedule is resumed.
 - ▶ These are given until the infants weigh 2,000-2,500 gm.
 - ▶ At discharge, premature infants are usually fed either breast milk or term formula (20 kcal/oz). Preterm post-discharge formula [transitional formula (22 kcal/oz), if available] may be used until 9-12 months corrected age.
- Specialized formulas: for milk protein allergy, malabsorption syndromes, and some IEMs.

Routes of Feeding

A) Nasogastric/orogastric feedings

Indications

Infants who are unable to nipple feed

- Preterm infants 32-34 wks' gestation according to the ability to coordinate suck-swallow-breathe pattern
- Neurological impairment (hypotonia or encephalopathy)
- Maxillofacial abnormalities
- Respiratory distress (respiratory rate 60-80 breaths/min)

Procedure

- Use a polyethylene orogastric or nasogastric tube (6 or 8Fr).
- Turn the infant's head to the side.

- Measure the length from the xiphoid to the ear lobe and then to the nose, and mark that length on the tube using a small piece of tape.
- Pass the tube through the nose or mouth with the neck in the flexed position.
- Inject air through the tube while auscultating the stomach for bubbling; then gently aspirate the stomach content.

B) Transpyloric feedings

Indications

- Infants at risk of aspiration (e.g., severe reflux).
- May be routinely used in ELBW infants

Procedure

- Insert orogastric tube as described above.
- Measure transpyloric tube (10 cm longer than orogastric tube).
- Turn patient onto the right side (with left hip up), and insert air through the orogastric tube to distend the stomach (10 ml for infants <1,000 gm & 15-20 ml for infants >1,000 gm).
- Insert the transpyloric tube.
- Wait 10-20 min with the neonate on right side and aspirate through the transpyloric tube gently; the tube is considered to be in a good position if aspirate is bilious, aspirate is alkaline & no air is aspirated
- If it is not in a good position, leave the transpyloric tube open and the orogastric tube closed for up to 4 hrs or until there is a bilious return. If unsuccessful within 4 hrs, repeat the entire procedure.

Methods of Feeding

Gavage (bolus) feeding

- Introduce feeding over 10-20 min (by gravity and not to inject by a syringe) every 2-3 hrs.
- Measure gastric residual before each feed.

Continuous drip feeding

- Indicated in infants with severe gastroesophageal reflux, ELBW infants and in transpyloric method.
- Use an automated pump; set rate at the desired hourly rate.

Gavage vs. continuous feeding

- Start with bolus feedings divided every 2-3 hrs. If feeding intolerance occurs, the time over which a feeding is given is to be lengthened by using syringe pump for 30-120 min.
- With gastric feeds, you can use gavage or continuous techniques. However, with transpyloric feeds, use only continuous technique.

Transition to breast/bottle feedings

- Infants who are 34 wks' gestation and who have coordinated suck-swallow-breathe patterns and RR <60 breaths/min are candidates for breast/bottle feeds.
- Begin oral feedings slowly at one feeding/day, increase as tolerated to once every 8 hrs, then once every 3rd feeding, then every other feeding, and finally to full nipple feedings.
- Schedule oral feedings for parent visits.
- Apply NNS on mother's emptied breasts or a pacifier during gavage tube feeds.

Supplements

- Preterm infants fed EBM without HMF should be started on a multivitamin supplement as soon as they are receiving full enteral nutrition.
- Preterm infants receiving EBM with HMF or standard preterm infant formulas do not routinely require additional vitamin supplements.
- Vitamin E supplementation (12 IU/kg/day) is recommended for preterm infants.
- Iron supplementation:
 - ▶ Start at 4 wks PNA once they are tolerating full enteral volumes of 24 kcal/oz feedings.

- ▶ Dose: 2-4 mg/kg/day for breast milk fed preterm infants for a total of 12 months (if fed a preterm infant formula, this will depend on the amount of iron in the formula).
- If HMF is unavailable, calcium and phosphorous are needed for premature infants receiving exclusive breast milk feeds; check serum Ca^{+2} , phosphorus & alkaline phosphatase levels regularly to determine any need for supplementation.
- After discharge:
 - ▶ Vitamin D: 200 IU/day (up to 400 IU/day) for all breast milk-fed infants beginning during the 1st 2 months of life.
 - ▶ Iron, as previously described (Table 16-4).

Table (16-4): Post-discharge Multivitamins & Iron Supplementation for Preterm Infants

If infant is Primarily On	What Supplements are Recommended?	When Can the Supplements be Stopped?
Breast milk	0.5 ml daily (Infant Multivitamin with Iron)	Continue until 12 months postnatal age (PNA)
Iron-fortified formula	0.5 ml daily (Infant Multivitamin <u>without</u> Iron)	Stop when intake reaches about 500-750 ml

Nutritional Assessment of Enteral-fed Preterm Infants

Table (16-5): Nutrition Assessment of Enteral-fed Preterm Infant

Parameter	Frequency of Measurement
Fluid Intake (ml/kg/day) <ul style="list-style-type: none"> • Enteral intake • Parenteral intake 	Daily
Nutritional Caloric Intake (kcal/kg/day)	Daily
Anthropometry	
<ul style="list-style-type: none"> • Weight (gm) • Length (cm) • Head circumference (cm) 	Daily at the same time Weekly Weekly

Table (16-5): Nutrition Assessment of Enterally-fed Preterm Infant (Cont'd)

Parameter	Frequency of Measurement
Biochemical Monitoring	
• Serum electrolytes	Twice weekly, then every 2 weeks*
• Albumin, BUN	Twice weekly, then every 2 weeks
• Calcium, phosphorus	Twice weekly, then every 2 weeks
• Alkaline Phosphatase	Twice weekly, then every 2 weeks
• Hemoglobin, hematocrit	Weekly
• Reticulocytes	Weekly
Other Assessments	
• Renal ultrasound	At 2 months of age (to evaluate for nephrocalcinosis)

*If infant is receiving breast milk or diuretics, BUN: blood urea nitrogen

Assessment of Feeding Tolerance

Table (16-6): Assessment of Feeding Tolerance

Parameter	Frequency of Measurement
Abdominal Girth	Before each feeding
Gastric Residual	Before each feeding
Vomiting	Every 8 hrs
Stools	
• Reducing substances	Every 8 hrs
• Heme-guaiac test	Daily
• Consistency	Each stool

Feeding Intolerance

Stop enteral feeds if any of the following signs are present:

- Clinical picture of NEC
- Acute onset of high residuals (>30% of a feed or >1 hr volume, if on continuous feeding)
- Bilious (or greenish) gastric residual

Chapter 16: Nutrition of At-Risk Infant

- Vomiting of the entire feed or vomiting associated with other signs of illness
- Acute increase of abdominal girth (>2 cm)
- Watery stool with reducing substances >0.5%
- GI bleeding or heme-positive stool

Residuals

- ↓Feeding volumes, slow the rate of instillation, or slow the rate of feeding advancement. If bile (check the site of the NG tube 1st by an x-ray film) or blood in the aspirate, consider NEC.

Emesis

- Allow feeding to flow more slowly (using small gavage tube), ↓feeding volumes and maintain a prone position. Consider prokinetic drugs. Stop feeding if infection, obstruction, metabolic disorders are suspected.

Abdominal distention

- If the abdomen is soft, maintain a prone position and gently stimulate the rectum with glycerin suppository. If signs of NEC are noted, do abdominal x-ray & measure abdominal girth every 4-8 hrs.

Watery diarrhea

- If the infant appears ill or if blood is noted in the stool, do a stool culture and stool Clinitest. In lactose malabsorption, use lactose free formula.

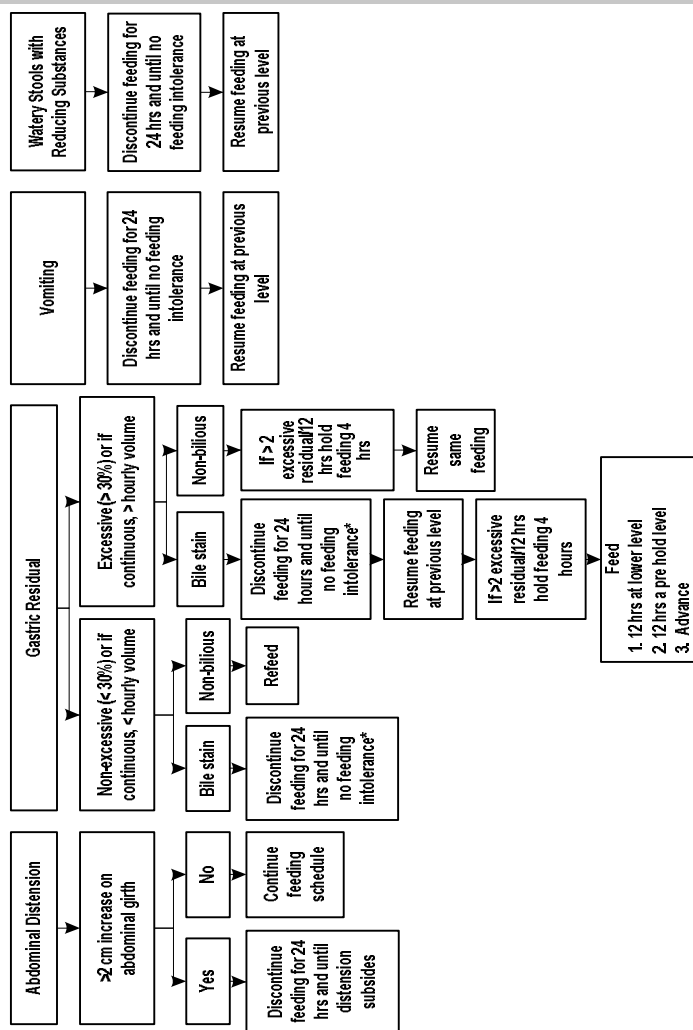
Blood in stools

- Discontinue feedings and consider obtaining clotting studies & abdominal radiograph.

Apnea and/or bradycardia

- Change to gavage tube feeding, ↓feeding volumes & feed slowly.

N.B.: If there is any doubt about how well an infant is tolerating feeds, it is best to hold feeds, evaluate and discuss with a senior staff member.



* The proper position of the NG tube should be checked by x ray 1st to exclude too deep insertion of the tube

Figure (16-1): Management of feeding intolerance

Parenteral Nutrition

Indications

PN should be considered in neonates who are not on significant enteral feeds for >3-5 days or are anticipated to be receiving <50% of total energy requirement by day 7 of life.

- Infants with birth weights <1,500 gm (often done in conjunction with slowly advancing enteral feeding).
- Infants with birth weights >1,500 gm and for whom significant enteral intake is not expected for >3 days (NEC, post-surgical & congenital GI anomalies).

Routes of Administration

- Peripheral vein
- Central vein: in ELBW and with an extended period (>7 days) of inability to take enteral feeding.

Components of Parenteral Nutrition

Fluid volume (Refer to Chapter 11)

Calories

- Goal: VLBW infants (90-100 kcal/kg/day), ELBW infants (105-115 kcal/kg/day) & term infants (80-90 kcal/kg/day).
- Provide calories primarily by carbohydrates & fats.
- Carbohydrates (50-55%), proteins (10-15% - should not exceed 15%) & fats (30-35% - should not exceed 50%).

Glucose

- 1 gm glucose provides 3.4 kcal.
- GIR are expressed in terms of mg of glucose/kg/min.
- Initial GIR 4-6 mg/kg/min in full term infants & 4-8 mg/kg/min in preterm infants, advance in daily increments of 1-2 mg/kg/min (maximum 11-12 mg/kg/min).
- Maintain normal plasma glucose levels.

- If hyperglycemia develops, ↓GIR; insulin may be required. ↑Protein intake 3-3.5 gm/kg may improve glucose tolerance. **Do not provide glucose at a rate <3 mg/kg/min.**

Lipids

- 1 gram lipid provides 9.1 kcal.
- Lipids can be started as early as the first day of life; start with 0.5-1 gm/kg/day and gradually advance by 0.5-1 gm/kg/day, as tolerated, to a maximum of 3 gm/kg/day.
- Administer slowly over 24 hrs via a separate syringe pump (rate should not exceed 0.12 gm/kg/hr). Syringes may be changed/12 hrs.
- Limit lipid infusion in infant with sepsis or severe lung disease, and restrict infusion to <2 gm/kg/day in infants with hyperbilirubinemia who are on phototherapy (especially if bilirubin levels are rising while on phototherapy).
- Monitor serum triglyceride level and adjust infusion rate to maintain triglyceride level <150-200 mg/dl (should be <150 mg/dl when the infant is jaundiced).

Protein

- 1 gram provides 4.0 kcal.
- Started on 1.5-2 gm/kg/day in the 1st 24 hrs after birth.
- Advance by 1 gm/kg/day to a target of 3.5 gm/kg/day for infants weighing <1,500 gm (up to 4 gm/kg/day in ELBW infants) and 3 gm/kg/day for infants weighing >1,500 gm.
- Maintain a non-protein calorie-to-protein ratio of at least 25-30:1 (i.e., Protein/Energy ratio: 3-4 gm/100 kcal).
- Advance more slowly in very unstable preterm infants and those with renal insufficiency or shock.
- Monitor BUN; if rising, do not increase the rate of infusion.

Electrolytes (Tables 16-7 & 16-8)

Table (16-7): Infant Daily Requirements of Electrolytes & Minerals

Nutrient	Daily Requirements
Sodium (Sodium Chloride)	3-4 mEq/kg
Potassium (Potassium Phosphate or Potassium Chloride)	2-3 mEq/kg
Calcium (Elemental)	50-100 mg/kg depending on size of the infant
Phosphorus (Potassium Phosphate or Sodium Phosphate)	1.5-2 mmol/kg (1 mmol of phosphorus = 31 mg)
Magnesium (Magnesium Sulfate)	0.25-0.5 mEq/kg (1mEq magnesium = 12.15 mg)
Chloride	3-7 mEq/kg

Table (16-8): Suggested Daily Parenteral Intakes of Electrolytes and Minerals for ELBW and VLBW Infants

Components (units/kg/day)	Day 0*	Transition**	Growing
Na (mEq)			
• ELBW infants	0-1	2-4	3-7
• VLBW infants	0-1	2-4	3-5
K (mEq)	0	0-2	2-3
Chloride (mEq)	0-1	2-4	3-7
Calcium (mg)	20-60	60	60-80
Phosphorus (mg)	0	45-60	45-60
Magnesium (mg)	0	3-7.2	3-7.2

*Recommended intake on the first day of life.

** Two to seven days of life.

Vitamins

- Add water- and fat-soluble vitamins as a pediatric multi-vitamin solution (standard dosage of 2 ml/kg/day [maximum 5 ml] in preterm infants and 5 ml in term infants).

- Vitamin A (5,000 IU IM/3 times/week) in ELBW infants who receive respiratory support at age 24 hrs is recommended.

Trace elements

- Zinc is recommended from day one of PN; the other trace elements are generally provided after two weeks.
- Pediatric trace metal solutions (0.2 ml/kg/day) and selenium 1.5 µg/dl. Additional zinc is needed in preterm infants.
- Discontinue copper and manganese in cholestatic infants (direct bilirubin >3 mg/dl).
- Chromium and selenium should be used with caution and in smaller amounts in the presence of renal dysfunction.
- Parenteral iron is recommended only when preterm infants are exclusively nourished by parenteral solutions for the first 2 months of life.

Precautions

- The 3-in-1 PN solutions (glucose, aminoacid and lipid mixed in single bag) should not be used.
- The continuity of a central line should not be broken for blood drawing or blood transfusion.
- Add heparin (0.5-1 unit/ml of solution) to all central lines.
- Medications should not be given in the same line with PN solutions. If necessary, PN catheter may be flushed with sterile water or normal saline before infusing medication.
- Lipid emulsions should be protected from light by wrapping lipid syringes and tubing in aluminum foil.

Monitoring (Table 16-9)**Weaning of TPN**

Parenteral nutrition, once initiated, should be continued until enteral feedings supply approximately 100-110 kcal/kg/day.

Monitoring Infants on Parenteral Nutrition

Table (16-9): Monitoring of Infants Receiving Parenteral Nutrition

Parameter	Frequency of measurement
Weight Length Head Circumference	Daily Weekly Weekly
Blood Gases	Daily until stable, then twice weekly
Serum Electrolytes (Na, K)	Daily until stable, then twice weekly
Blood Glucose Level	<ul style="list-style-type: none"> • 1st week: every 6 hrs the first 2 days, then every 12 hrs • After the 1st week: daily
BUN and Serum Creatinine	Weekly
Serum Calcium, Phosphorus, Magnesium and Alkaline phosphatase	Weekly
Total and Direct Bilirubin, ALT, AST	Weekly
Total Protein and Albumin	Weekly
Serum Triglycerides	Weekly
Hematocrit	Weekly
Urine <ul style="list-style-type: none"> • Volume • Specific Gravity • Glucosuria 	Daily First week: each urine sample, then once per shift

BUN; Blood urea nitrogen, ALT; Alanine transaminase, AST; Aspartate transaminase

Complications

- Sepsis and skin infection (*staph. epidermidis* & *staph. aureus* are the most common pathogens) and fungal infection
- Hepatic dysfunction and cholestasis

- ▶ Normal bile flow usually returns when PN is stopped and enteral feeding is begun.
- ▶ Start MEN in combination with PN in infants with TPN-associated cholestasis who require continued PN.
- Hyperglycemia or hypoglycemia
- Azotemia, hyperammonemia & metabolic acidosis if amino-acid intake >4 gm/kg/day.
- Metabolic bone disease
- Complications related to lipid emulsion
 - ▶ Hyperlipidemia & hypertriglyceridemia: ↓lipid infusion if serum triglyceride level between 200-300 mg/dl and stop lipid infusion if serum triglyceride level >300 mg/dl.
 - ▶ Indirect hyperbilirubinemia
 - ▶ Sepsis: during sepsis episode, limit lipid infusion to 2 gm/kg/day, if triglyceride level is >150 mg/dl.
 - ▶ Chronic lung disease

N.B.: Do not withhold lipids completely for >48-72 hrs (0.5 gm/kg/day will prevent fatty acid deficiency).

CHAPTER 17

Hyperbilirubinemia

Clinical jaundice is diagnosed if the total serum bilirubin is ≥ 7 mg/dl.

Unconjugated Hyperbilirubinemia

Etiology

Table (17-1): Causes of Neonatal Hyperbilirubinemia

↑Bilirubin Production	Hemolytic diseases <ul style="list-style-type: none"> • Isoimmune (Rh, ABO & other blood group incompatibilities) • Non-immune (G6PD deficiency, spherocytosis & α-thalassemia) Extravasated blood <ul style="list-style-type: none"> • Cephalhematoma • Extensive bruises Polycythemia Sepsis
↓Bilirubin Uptake	Gilbert syndrome
↓Bilirubin Conjugation	Crigler-Najjar syndrome (types I & II) Gilbert syndrome Lucey-Driscoll Syndrome Hypothyroidism
↑Enterohepatic Circulation	Pyloric stenosis Bowel obstruction Delayed passage of meconium
Uncertain Mechanism	Breast milk jaundice

Table (17-2): Risk Factors for Development of Severe Hyperbilirubinemia in Infants of ≥ 35 wks' Gestation

Major Risk Factors	Minor Risk Factors	Decreased Risk
<ul style="list-style-type: none"> • PredischARGE TSB or TcB levels in the high-risk zone • GA 35-36 wks • Jaundice observed in the first 24 hrs • Blood group incompatibility • Previous sibling received phototherapy • Cephalhematoma or significant bruising • Exclusive breast-feeding, particularly if nursing is not going well and weight loss is excessive • East Asian race 	<ul style="list-style-type: none"> • PredischARGE TSB or TcB levels in the high intermediate-risk zone • GA 37-38 wks • Jaundice observed before discharge • Previous sibling with jaundice • Macrosomic infant of a diabetic mother • Maternal age ≥ 25 years • Male gender 	<ul style="list-style-type: none"> • TSB or TcB levels in the low-risk zone • GA ≥ 41 wks • Exclusive bottle feeding • Black race* • Discharge from hospital after 72 hrs

* Race as defined by mother's description

TSB: total serum bilirubin, TcB: transcutaneous bilirubin, G6PD: glucose-6-phosphate dehydrogenase, GA: gestational age, Wk: week

(From the Subcommittee on Hyperbilirubinemia. Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. Pediatrics 2004; 114:297-316).

Physiologic Hyperbilirubinemia

- In full term healthy infants, jaundice becomes visible on the 2nd-3rd day, peaking between the 2nd-4th days at 5-6 mg/dl, and disappearing by 6th-8th days of life (may last up to the 14th day with a maximum TSB level <12 mg/dl).
- In preterm infants, jaundice is more severe with mean peak TSB level reaching 10-12 mg/dl by the 5th day of life.

Chapter 17: Hyperbilirubinemia

- All newborns, especially those who are at high risk for developing high levels of bilirubin should be followed closely using the “Hour-specific bilirubin nomogram” (Figure 17-1).
- The 95th percentile of maximal TSB level in healthy mature newborn is 12.4 mg/dl for formula-fed infants & 14.8 mg/dl for breastfed infants.

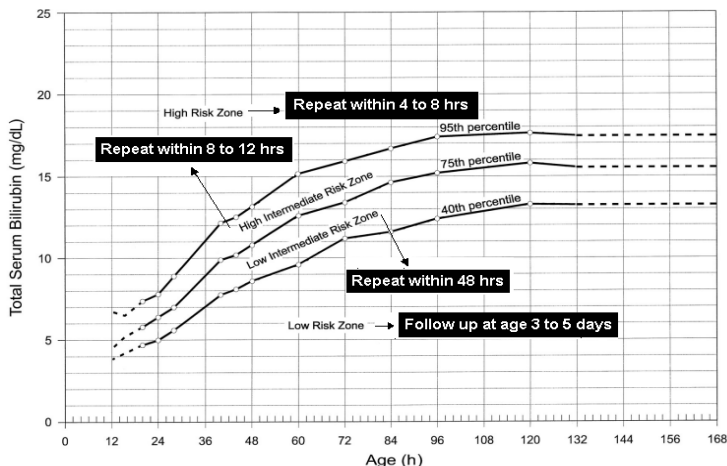


Figure (17-1): Hour-specific bilirubin nomogram

Risk designation of term and near-term well newborns based on their hour-specific serum bilirubin values. The high-risk zone is designated by the 95th percentile track. The intermediate-risk zone is subdivided to upper- and lower-risk zones by the 75th percentile track. The low-risk zone has been electively and statistically defined by the 40th percentile track (From Bhutani VK, Johnson L. A proposal to prevent severe neonatal hyperbilirubinemia and kernicterus. *Journal of Perinatology*, 2009; 29: S61-S67).

Nonphysiologic Hyperbilirubinemia

Criteria

- Clinical jaundice in the first 24 hrs of life
- TSB level increasing by >0.2 mg/dl/hr or 5 mg/dl/day
- TSB level >95th percentile for age in hours

- Direct serum bilirubin >2 mg/dl
- Clinical jaundice persisting >8 days in full term infants & >14 days in preterm infants
- Signs of illness (vomiting, lethargy, poor feeding, excessive weight loss, apnea, tachypnea, or temperature instability)

Jaundice Associated with Breastfeeding

Breastfeeding jaundice (not-enough breast milk jaundice)

Early onset, accentuated unconjugated hyperbilirubinemia occurs in the first week of life in breastfed infants due to insufficient breast milk and irregular feeding.

Breast milk jaundice (late onset)

Rarely serious condition and should be considered if:

- By day 4 of life, bilirubin level continues to rise instead of decreasing. It may reach 20-30 mg/dl by 14 days of age.
- If breastfeeding is continued, levels will stay elevated & then fall slowly at 2 wks of age, returning to normal by 4-12 wks.
- Stopping breast milk \rightarrow rapid fall in serum bilirubin within 48 hrs; resumption of breastfeeding increases bilirubin levels slightly but usually below previous levels (this is not routinely recommended).
- Infants have good weight gain, normal liver function tests and no evidence of hemolysis.

Diagnosis of Unconjugated Hyperbilirubinemia

History

- Day of onset of jaundice
- Maternal blood group & Rh
- Family history of jaundice, anemia, splenectomy
- Family history of liver disease
- Previous sibling with jaundice or anemia
- Maternal disease (diabetes mellitus or immune disorder)
- Maternal drug intake (e.g., sulfonamides, aspirin, of antimalarials)

Chapter 17: Hyperbilirubinemia

- Traumatic delivery, delayed cord clamping, or asphyxia
- Vomiting, infrequent stooling, delayed breastfeeding
- The infant is breastfed or formula-fed

Examination

Observe in good daylight. Jaundice progresses in cephalocaudal direction (Table 17-3).

Table (17-3): Progression of Skin Involvement by Jaundice

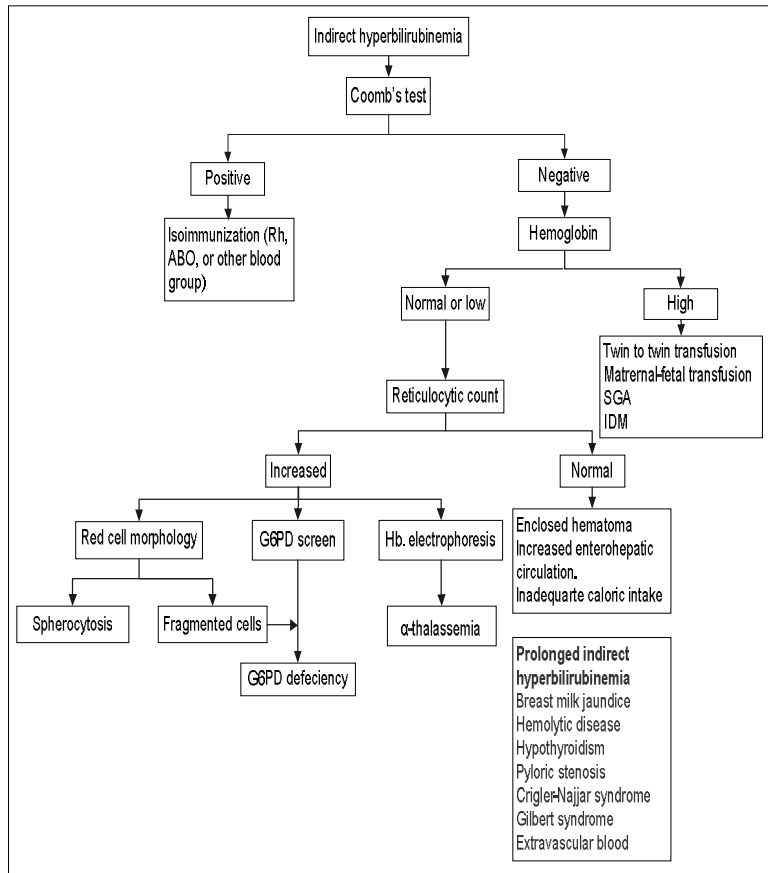
Clinical Extent	Grade
None	0
Limited to the head and neck	1
Involves the (chest and upper abdomen) and/or back	2
Involves the abdomen below the umbilicus to the knees	3
Involves the legs below the knees and/or upper and lower arms	4
Involves hands and/or feet	5

- Infants with jaundice should be examined for:
 - ▶ Prematurity or SGA
 - ▶ Microcephaly
 - ▶ Extravasated blood (e.g., cephalhematoma or bruises)
 - ▶ Pallor, plethora, petechiae
 - ▶ Hepatosplenomegaly
 - ▶ Signs of hypothyroidism (large anterior fontanelle, delayed passage of meconium, hypothermia, mottled skin and poor feeding)
 - ▶ Signs of sepsis
 - ▶ Color of jaundice: orange yellow = ↑unconjugated and olive green = ↑conjugated
 - ▶ Signs of bilirubin encephalopathy (kernicterus)

Laboratory investigations

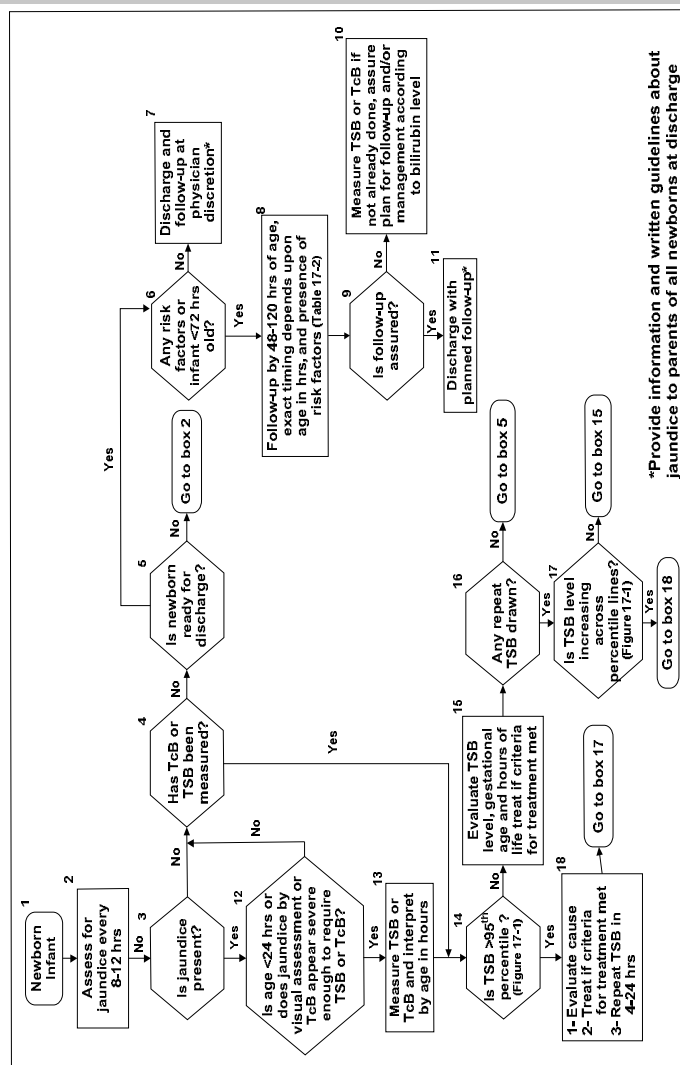
- Serum bilirubin total and direct
- Blood group and Rh of the infant and the mother

- Coomb's test
- CBC (Hb, Hct, WBC total & differential, red cell morphology)
- Reticulocytic count



IDM: Infant of a diabetic mother, SGA: Small for gestational age, G6PD: Glucose-6-phosphate dehydrogenase, Hb: Hemoglobin

Figure (17-2): Diagnostic approach to neonatal indirect hyperbilirubinemia



TSB: total serum bilirubin, TcB: transcutaneous bilirubin

Figure (17-3): Algorithm for the management of jaundice in the newborn nursery

(From the Subcommittee on hyperbilirubinemia Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation, Pediatrics 2004;114:297-316).

Prediction of Non-Physiologic Hyperbilirubinemia

- A screening TSB collected predischarge from newborn nursery and plotted on an “hour specific bilirubin nomogram”
- TcB, in infants >30 wks' gestation, can be used as a screening tool to identify infants at high risk of severe hyper-bilirubinemia. If the TcB is >8, check TSB.
- TcB is not reliable after initiation of phototherapy.
- Timing of post-discharge follow-up depends on the age at discharge and the presence of risk factors.

Table (17-4): Timing of Post-discharge Follow-up

Infant discharge	Should be seen by age
Before age 24 hrs	72 hrs
Between 24 and <47.9 hrs	96 hrs
Between 48 and 72 hrs	120 hrs
<p>Some newborns discharged before 48 hrs, may require two follow-up visits (the 1st between 24-72 hrs and the 2nd between 72-120 hrs). Clinical judgment should be used in determining follow-up. Earlier or more frequent follow-up should be provided for those who have risk factors for hyperbilirubinemia, whereas those discharged with few or no risk factors can be seen after longer intervals.</p> <p>(From the Subcommittee on Hyperbilirubinemia. Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. Pediatrics 2004; 114:297-316).</p>	

Management of Unconjugated Hyperbilirubinemia

- Increase feeds in volume and calories
- Avoid routine supplementation with water or glucose water or medications.
- Stop drugs that interfere with bilirubin metabolism.
- Correct hypoxia, infection and acidosis.
- Refer to **(Figures 17-4), (Figure 17-5), (Table 17-5), and (Table 17-6)** for treatment option guidelines.

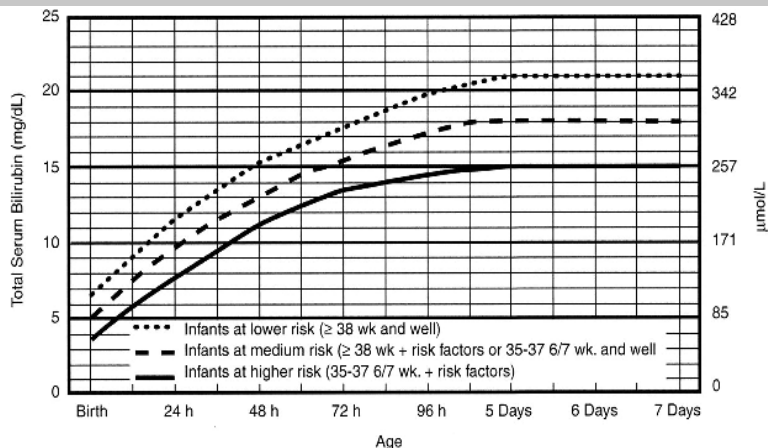


Figure (17-4): Guidelines for phototherapy in infants ≥ 35 wks' gestation

- Use total bilirubin. Do not subtract direct reacting or conjugated bilirubin.
- Risk factors = isoimmune hemolytic disease, G6PD deficiency, asphyxia, significant lethargy, temperature instability, sepsis, acidosis, or albumin $< 3\text{g/dl}$ (if measured)
- For well infants 35-37 6/7 wks can adjust TSB levels for intervention around the medium risk line. It is an option to intervene at lower TSB levels for infants closer to 35 wks and at higher TSB levels for those closer to 36 6/7 wks.
- It is an option to provide conventional phototherapy in hospital or at home at TSB levels 2-3 mg/dl (35-50 $\mu\text{mol/L}$) below those shown, but home phototherapy should not be used in any infant with risk factors.

(Reprinted with permission from the Subcommittee on Hyperbilirubinemia Management of hyperbilirubinemia in the newborn infant 35 or more weeks of gestation. Pediatrics 2004; 114:297-316).

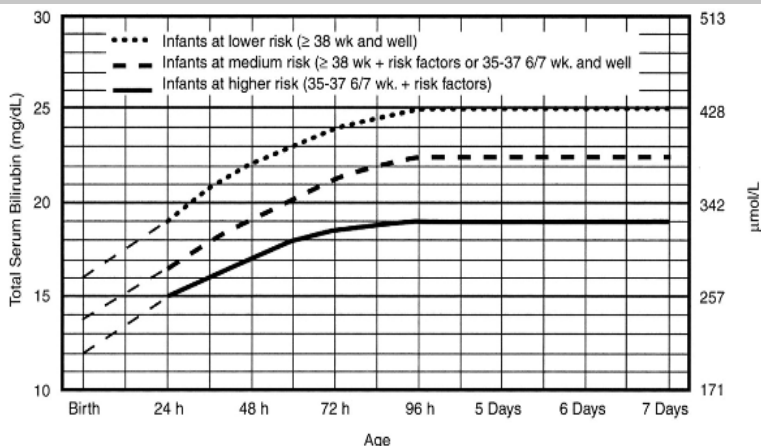


Figure (17-5): Guidelines for exchange transfusion in infants ≥ 35 wks' gestation

- The dashed lines for the 1st 24 hours indicate uncertainty due to a wide range of clinical circumstances and a range of responses to phototherapy.
- Immediate exchange transfusion is recommended if infant shows signs of acute bilirubin encephalopathy (hypertonia, arching, retrocollis, opisthotonos, fever, high pitched cry) or if TSB is ≥ 5 mg/dl (85 μ mol/L) above these lines.
- Risk factors-isoimmune hemolytic disease, G6PD deficiency, asphyxia, significant lethargy, temperature instability, sepsis, acidosis.
- Measure serum albumin and calculate B/A ratio
- Use total bilirubin. Do not subtract direct reacting or conjugated bilirubin.
- If infant is well and 35-37 6/7 wks (medium risk) can individualize TSB levels for exchange based on actual gestational age.

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Table (17-5): Management of Hyperbilirubinemia in Healthy and Sick Premature Infants (<37 weeks' gestation)

Weight (gm)	Healthy Infants: Total Serum Bilirubin Level (mg/dl)		Sick Infants: Total Serum Bilirubin Level (mg/dl)	
	Phototherapy	Exchange Transfusion	Phototherapy	Exchange Transfusion
≤ 1,000*	5-7	10-12	4-6	8-10
1,001-1,500	7-10	12-15	6-8	10-12
1,501-2,000	10-12	16-18	8-10	14-16
2,001-2,500	12-15	18-20	10-12	16-18

* For infants <1,000 gm; prophylactic phototherapy may be started within the first 24 hrs.

Table (17-6): Bilirubin/Albumin (B/A) Ratio at which Exchange Transfusion should be Considered

Risk Category	B/A ratio TSB (mg/dl)/ Albumin (g/dl)
Infants ≥38 0/7 wks	8.0
Infants 35 0/7 -36 6/7 weeks and well, or infants ≥38 0/7 wks if higher risk or isoimmune hemolytic disease or G6PD deficiency	7.2
Infants 35 0/7-37 6/7 wks if higher risk or isoimmune hemolytic disease or G6PD deficiency	6.8

N.B.: Bilirubin levels refer to the total bilirubin. Direct bilirubin is not subtracted from the total unless it constitutes >50% of the total bilirubin.

- The bilirubin/albumin (B/A) ratio can be used together with, but not in lieu of, the TSB level as an additional factor in determining the need for exchange transfusion.

Phototherapy

- Indications
 - ▶ According to the guidelines in (Figure 17-4) & (Table 17-5)

- ▶ Bilirubin level approaches the toxic range
- ▶ Prophylactic for ELBW infants & severely bruised infants
- ▶ During the wait for exchange transfusion
- Technique
 - ▶ The infant should be undressed except for a diaper and eye patches (eye patches must be in place but should not be too tight or occlude the nares).
 - ▶ Place 5-8 cm over the incubator and 45 cm above the infant.
 - ▶ Give continuously and turn the infant every 2 hrs.
 - ▶ Maintain a NTE; infant's temperature should be carefully monitored and servo-controlled.
 - ▶ Weigh the infants daily (twice daily in small infants).
 - ▶ Carefully monitor infant's fluid balance must also be carefully monitored (↑fluid therapy by 20%).
- The frequency of TSB measurements depends upon the initial TSB value.
 - ▶ When infant is admitted with TSB level >95th percentile for hour-specific TSB levels: measure TSB 2-3 hrs after initiation of phototherapy.
 - ▶ When phototherapy is started for a rising TSB: measure TSB after 4-6 hrs, and then within 8-12 hrs, if TSB continues to fall.
- If, despite intensive phototherapy, TSB is at or approaches the threshold for exchange transfusion, send a blood sample for immediate typing and cross-matching.
- Once started, the skin color cannot be taken as a guide to the level of hyperbilirubinemia.
- Side effects: hyperthermia, dehydration, watery diarrhea, hypocalcemia, retinal damage, erythema, bronze baby syndrome (infants with direct hyperbilirubinemia), potential genetic damage & upsets of maternal infant interaction.
- Discontinuation, when the following criteria are met:
 - ▶ Bilirubin level is low enough to eliminate risk of kernicterus
 - ▶ Infant is old enough to handle the bilirubin load

- Measure TSB 18-24 hrs after phototherapy is terminated.

Exchange transfusion

- Double blood volume exchange = $2 \times 80 \text{ ml} \times \text{weight (kg)}$
- Type of blood: fresh citrated blood is used
 - ▶ In Rh-incompatibility, use Rh -ve blood, cross-matched with the mother's blood if prepared before delivery and also cross matched with the infant if the blood is obtained after delivery.
 - ▶ In ABO incompatibility, use O+ve or O-ve group (cross-matched with both the infant's and mother's blood).
 - ▶ In other isoimmune hemolytic disease, blood should be cross matched with the mother's blood.
 - ▶ In other cases, use the infant's group after cross-matching with the infant's blood.
- Albumin transfusion (1 gm of albumin, 1 hr before exchange transfusion) may be useful, if bilirubin levels >20 mg/dl & serum albumin levels <3 gm/dl. Monitor fluid volume and cardiovascular status carefully before transfusion.

Pharmacologic agents

- Intravenous immunoglobulin (IVIG 500-1,000 mg/kg IV over 2-4 hrs) is recommended in immune hemolytic type, if TSB is rising despite intensive phototherapy or is within 2-3 mg/dl of the threshold for exchange transfusion. Dose may be repeated in 12 hrs, if necessary.
- Phenobarbital: not used except in Crigler-Najjar syndrome type II.

Bilirubin Encephalopathy (Kernicterus)

Factors influencing risk of kernicterus

- ↓Albumin binding capacity: prematurity, asphyxia, acidosis, hypoalbuminemia & infections.
- Displacement of bilirubin from albumin binding sites by drugs (e.g., synthetic vitamin K, sulfonamide, gentamicin), or free fatty acids (hypoglycemia, starvation, or hypothermia).

- ↑Susceptibility to bilirubin toxicity: asphyxia, hypoglycemia

Clinical manifestations

A) *Acute bilirubin encephalopathy* (3 phases)

- Early: hypotonia, lethargy, high-pitched cry & poor suckling
- Intermediate: hypertonia of extensors (opisthotonus, oculogyric crises & retrocollis), irritability, seizures & fever.
- Advanced: pronounced opisthotonus, shrill cry, apnea, seizures, coma & death.

B) *Chronic bilirubin encephalopathy (kernicterus)*

- Athetosis, deafness, limitation of upward gaze, dental dysplasia and intellectual deficits.

Management

- If bilirubin toxicity is suspected, do an immediate exchange transfusion (initiate phototherapy until exchange starts).
- Exchange transfusion should be done in cases with clinically established kernicterus.

Conjugated Hyperbilirubinemia

Increased direct bilirubin level >15% of the total serum bilirubin

Approach to Neonatal Cholestasis (Figure 17-6)

Management

- Supportive management
 - ▶ Formulas containing medium-chain triglycerides
 - ▶ Fat soluble vitamins supplementation (A, D, E & K).
 - ▶ Ursodeoxycholic acid (15 mg/kg/day, in 2 divided doses).
- Treatment of the cause

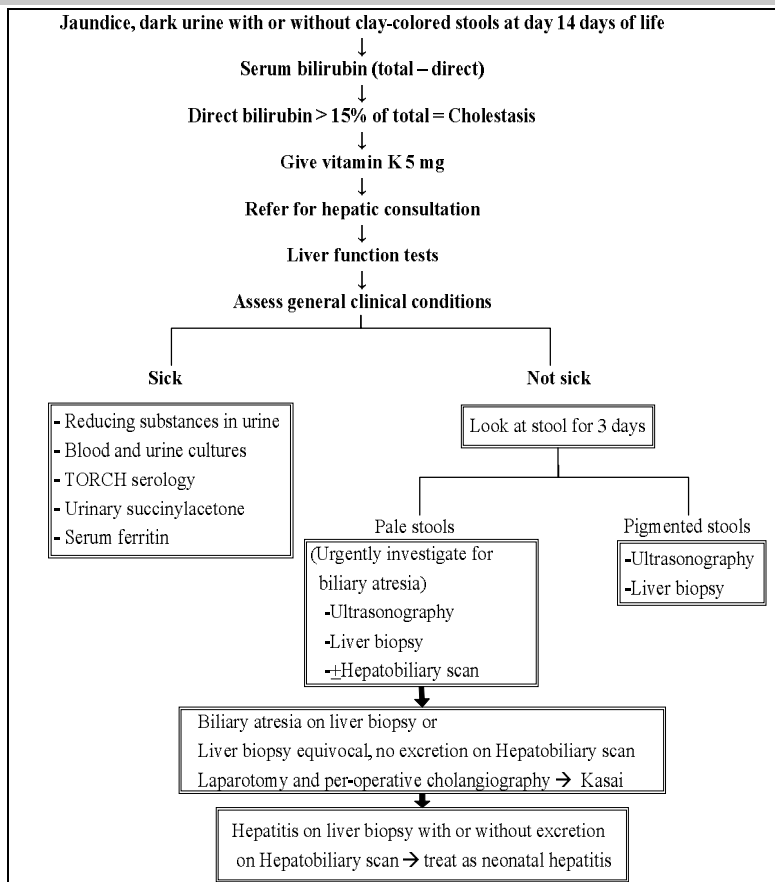


Figure (17-6): An approach to neonatal cholestasis

N.B.: Phototherapy should not be used in cases of conjugated hyperbilirubinemia. If both direct and indirect bilirubin are high, exchange transfusion is probably safer than phototherapy.

CHAPTER 18

Neonatal Respiratory Disorders

Etiology

Table (18-1): Causes of Respiratory Distress in Neonates

Pulmonary causes	Extra-pulmonary causes
<ul style="list-style-type: none"> • TTN • RDS • Pneumonia • MAS • Pulmonary hemorrhage 	<ul style="list-style-type: none"> • Cardiac causes (CHD cyanotic or acyanotic & CHF) • PPHN • Neurological (e.g., prenatal asphyxia, meningitis) • Diaphragmatic disorders (e.g., congenital diaphragmatic hernia, diaphragmatic paralysis) • Chest wall deformities • Metabolic (e.g., hypoglycemia, hypothermia or hyperthermia) • Metabolic acidosis • Hematological causes (e.g., anemia, polycythemia)

TTN: transient tachypnea of the newborn, RDS: respiratory distress syndrome, MAS: meconium aspiration syndrome, CHD: congenital heart disease, PPHN: persistent pulmonary hypertension

Evaluation (Downes' Score) (Table 18-2)

General Management of Respiratory Distress

- Supplemental oxygen or MV, if needed.
- Continuously monitor with pulse oximeter.
- Obtain a chest radiograph.
- Provide appropriate fluids & NTE (fluid restriction be equal to urine output (1-3 ml/kg/hr) & IWL may be needed).

- Correct metabolic abnormalities (acidosis, hypoglycemia).
- Provide an adequate nutrition. Infants with sustained RR >60 breaths/min should not be fed orally & should be maintained on gavage feedings for RR 60-80 breaths/min, and NPO with IV fluids or TPN for more severe tachypnea.
- Obtain a blood culture & begin an antibiotic coverage (ampicillin + gentamicin) while awaiting the results of the culture, in preterm infants with respiratory distress or a term infants with respiratory distress that persists >4-6 hrs, or if sepsis or pneumonia is suspected.
- Provide an appropriate specific therapy.

Table (18-2): Evaluation of Respiratory Distress (Downes' Score)

Test	Score		
	0	1	2
Respiratory rate	<60/minute	60-80/minute	>80/minute
Retractions	No retractions	Mild retractions	Severe retractions
Cyanosis	No cyanosis	Cyanosis relieved by O ₂	Cyanosis on O ₂
Air entry	Good bilateral air entry	Mild decrease in air entry	No air entry
Grunting	No grunting	Audible by stethoscope	Audible with ear
Evaluation			
Total	Diagnosis		
<4	No respiratory distress		
4-7	Respiratory distress		
>7	Impending respiratory failure; blood gases are required		

Transient Tachypnea of the Newborn (TTN)

TTN is a mild, self limiting disorder of near-term or term infants.

Risk Factors

- Elective CS delivery
- Macrosomia & IDM's
- Prolonged labor
- Excessive maternal sedation or fluid overload given to the mother, especially with oxytocin infusion
- Delayed umbilical cord clamping

Clinical Manifestations

- Infant is usually near-term or term and presents within 6 hrs after delivery with tachypnea (>80 breaths/min).
- Mild to moderate respiratory distress with grunting, nasal flaring, rib retraction & cyanosis.
- Auscultation reveals good air entry with or without crackles.
- Manifestations usually persist for 12-24 hrs (up to 72 hrs in more severe cases).
- Exclude other causes of respiratory distress in the first 6 hrs of life (e.g., pneumonia, RDS, CHD, or HIE). Spontaneous improvement is an important marker of TTN.

Investigations

- CBC with differential and CRP to rule out sepsis.
- Blood gas analysis: hypoxemia, PaCO₂ is usually low (or may be mildly elevated); if respiratory failure occurs, another diagnosis should be considered.
- Chest x-ray (the typical findings in TTN)
 - ▶ Prominent perihilar streaking
 - ▶ Fluid in the minor fissure
 - ▶ Prominent pulmonary vascular markings
 - ▶ Lung hyperinflation with depression of diaphragm

- Chest x-ray usually shows evidence of clearing by 12-18 hrs with complete resolution by 48-72 hrs.

Management

- Follow general management rules.
- Start antibiotic therapy, depending on the history & clinical status of the infant, and you can terminate at 48-72 hrs, if cultures are negative.
- No role for diuretics.

Respiratory Distress Syndrome (RDS)

RDS (or hyaline membrane disease) primarily affects preterm infants.

Risk Factors

Table (18-3): Risk Factors for Respiratory Distress Syndrome

↑Risk	↓Risk
<ul style="list-style-type: none">• Prematurity• Maternal diabetes• Multiple births• Elective CS without labor• Perinatal asphyxia• Cold stress• Genetic disorders of surfactant production (e.g., surfactant protein B mutation)	<ul style="list-style-type: none">• Chronic intrauterine stress• Prolonged rupture of membranes• Antenatal steroid prophylaxis

CS: Cesarean section

Clinical Manifestations

- Manifestations usually appear within minutes of birth, although they may not be recognized for several hours in larger preterm infants.
- Tachypnea (>60 breaths/min), nasal flaring, subcostal and intercostal retractions, cyanosis & expiratory grunting.

- Breath sounds may be normal or diminished and fine rales may be heard, especially over lung bases.
- Progressive worsening of cyanosis & dyspnea. BP may fall; fatigue, cyanosis and pallor increase & grunting decreases.
- Apnea and irregular respirations are ominous signs, indicating hypoxemia & respiratory failure.
- In most cases, symptoms and signs reach a peak within 3 days, after which improvement occurs gradually.

Investigations

- Blood gas analysis
- Sepsis work-up (CBC with differential, CRP, and blood culture) to rule out early-onset sepsis.
- Serum glucose and electrolyte levels monitoring
- Chest x-ray: findings can be graded according to the severity
 - ▶ Grade 1 (mild cases): the lungs show fine homogenous ground glass shadowing
 - ▶ Grade 2: widespread air bronchogram become visible
 - ▶ Grade 3: confluent alveolar shadowing
 - ▶ Grade 4: complete white lung fields with obscuring of the cardiac shadow

Management

Prevention

- Antenatal corticosteroid therapy (betamethasone 12 mg/dose IM for 2 doses, 24 hrs apart, or dexamethasone 6 mg/dose IM for 4 doses, 12 hrs apart) for pregnant women 24-34 wks' gestation at high risk of preterm delivery within the next 7 days.
- Prophylactic surfactant therapy in preterm infants <27 wks' gestation.
- Early CPAP administration in the delivery room.

Treatment

- Follow general management rules.

- Administer oxygen (depending on the severity of illness).
- Initiate CPAP as early as possible in infants with mild RDS who require an FiO_2 below 0.4 to maintain the target SaO_2 and have $\text{PaCO}_2 < 55\text{-}60$ mmHg.
- Start MV if respiratory acidosis ($\text{PaCO}_2 > 60$ mmHg, $\text{PaO}_2 < 50$ mmHg or $\text{SaO}_2 < 90\%$) with an $\text{FiO}_2 > 0.5$, or severe frequent apnea.
- Administer surfactant therapy: early rescue therapy within 2 hrs after birth is better than late rescue treatment when the full picture of RDS is evident.

Meconium Aspiration Syndrome (MAS)

Meconium staining of the amniotic fluid indicates fetal distress.

Risk Factors

Post-term pregnancy, pre-eclampsia, eclampsia, maternal hypertension, maternal diabetes mellitus, IUGR, and evidences of fetal distress (e.g., abnormal biophysical profile)

Clinical Manifestations

- Meconium staining amniotic fluid (ranging from thin, green-stained fluid to thick, pea soup consistency)
- Signs of postmaturity (weight loss, meconium stained nails, skin & umbilical cord)
- Aspiration of large amounts of thick meconium (if not removed by ET suctioning → acute large airway obstruction)
- Partial distal airway obstruction → respiratory distress soon after birth. Infants with severe MAS have "barrel" chest.
- Some infants may have mild initial respiratory distress, which becomes more severe hours after delivery.
- Pneumothorax and/or pneumomediastinum
- PPHN in severe cases
- Hypoxia to other organs (e.g., seizures, oliguria)

Investigations

- CBC with differential
- Blood gas analysis
- Chest x-ray: patchy infiltrates, coarse streaking of both lung fields, ↑anteroposterior diameter, and flat diaphragm.
- Surveillance for end organ hypoxic damage including kidney function tests and cranial ultrasonography.

Management

Prenatal

- Identification of high-risk pregnancy
- Monitoring of FHR during labor

In the DR or OR (if amniotic fluid is meconium stained)

- Suctioning of the oropharynx before delivery of the shoulders is not recommended. Visualization of the vocal cords & tracheal suctioning before ambu-bagging should be done only if the baby is not vigorous (**Refer to Chapter 2**).

In the NICU

- Follow general management rules.
- Empty stomach contents to avoid further aspiration.
- Suction frequently & perform chest physiotherapy.
- Maintain an antibiotic coverage (ampicillin & gentamicin).
- Give supplemental oxygen (maintain PaO_2 at least in the range of 80-90 mmHg).
- Consider CPAP, if FiO_2 requirements >0.4 ; however CPAP may aggravate air trapping and must be used cautiously.
- Mechanical ventilation: in severe cases ($\text{paCO}_2 >60$ mmHg or persistent hypoxemia ($\text{paO}_2 <50$ mmHg)).
- Correct systemic hypotension (hypovolemia, myocardial dysfunction).
- Manage PPHN, if present (**Refer to Chapter 31**).

- Manage seizures or renal problems, if present.
- Surfactant therapy in infants whose clinical status continue to deteriorate.

Complications

Air leak, PPHN, pneumonia, BPD, and airway reactivity

Air Leak Syndromes

Risk Factors

MV, MAS, surfactant therapy without decreasing pressure support in ventilated infants, vigorous resuscitation, prematurity, and pneumonia

Pneumothorax

- Spontaneous pneumothorax may be asymptomatic or only mildly symptomatic (i.e., tachypnea and $\uparrow O_2$ needs).
- In unilateral cases, chest asymmetry is noted, hyper-resonant chest on percussion and mediastinum shift to the opposite side.
- If the infant is on ventilatory support, he/she will have sudden onset of clinical deterioration (i.e., cyanosis, hypoxemia, hypercarbia & respiratory acidosis associated with decreased breath sounds and shifted heart sounds).
- Tension pneumothorax (a life-threatening condition) \rightarrow \downarrow cardiac output and obstructive shock; urgent drainage prior to a radiograph is mandatory.
- Chest x-ray may show just minimal differences in lucency of lung fields (in case of spontaneous pneumothorax) or jet black lung and shift of mediastinum to the opposite side (in case of tension pneumothorax).

Pulmonary Interstitial Emphysema (PIE)

- Commonly seen in small preterm infants with significant RDS in the first 48 hrs of life.
- Chest x-ray reveals radiolucencies [linear (radiate from lung hilum) or cyst-like (1-4 mm in diameter)].

Pneumomediastinum

- It can occur with aggressive ETT insertion, Ryle's feeding tube insertion, lung disease, MV, or chest surgery (e.g., TEF).

Others

- Pneumopericardium
- Pneumoperitoneum
- Subcutaneous emphysema
- Systemic air embolism

Investigations

- Blood gas analysis
- Chest x-ray (anteroposterior and lateral views)
- Transillumination test

N.B.: Needle aspiration should be done for suspected cases of pneumothorax with deteriorating general condition until intercostal tube is inserted.

Management

- Prevention: judicious use of ventilatory support, close attention to distending pressures (PIP & PEEP) and Ti. Appropriate weaning as the clinical condition improves.
- Follow general management rules.
- Specific therapy
 - ▶ Conservative therapy (in spontaneous pneumothorax and non-ventilated cases): close observation of the degree of respiratory distress and SaO₂ aiming at spontaneous resolution.
 - ▶ Decompression of pneumothorax (**Refer to Chapter 38**)

Pneumonia

Etiology

- Common: GBS, gram-ve organisms (e.g. *E.Coli*, *Klebsiella*, *Pseudomonas*), *Staph. aureus*, *Staph. epidermidis* & *Candida*.

- Less common: acquired viral infections (e.g., HSV, CMV).

Clinical Manifestations

- Manifestations are apparent prior to delivery (e.g., fetal distress, tachycardia), at delivery (e.g., perinatal asphyxia) or after a few hours (e.g., respiratory distress, shock).
- Early manifestations may be nonspecific (e.g., poor feeding, lethargy, irritability, cyanosis, temperature instability & the overall impression that the infant is not well).
- Respiratory distress, cyanosis, apnea & progressive respiratory failure may become evident. In preterm infants, these signs may be superimposed upon RDS or BPD.
- In a ventilated infant, the most prominent change may be the need for an increased ventilatory support.
- Signs of pneumonia (dullness to percussion, change in breath sounds, rales or rhonchi) are difficult to appreciate.
- Pyogenic organisms (e.g., GBS) → fulminant infection. Onset is usually during the first hours or days of life with rapidly progressive circulatory collapse and respiratory failure.

Investigation

- Chest x-rays: infiltrates or effusion (if the neonate has an underlying RDS or BPD, it is difficult to determine whether the radiographic changes represent a new process or worsening of the underlying disease)
- Work-up for sepsis: CBC with differential & CRP
- Tracheal aspiration & blood culture

Management

- Follow general management rules.
- Initiate ampicillin and gentamicin IV; modify according to culture results and continue therapy for 14 days.
- If there is a fungal infection, an antifungal agent is used.

Apnea and Bradycardia

Apnea is the absence of breathing for >20 seconds or a shorter pause associated with O₂ desaturation or bradycardia (<100 beats/min). Periodic breathing is respiratory pauses <10 seconds with normal or rapid respirations between episodes; it is not associated with bradycardia.

Classification

- Obstructive apnea: when the infant's neck is overflexed or hyperextended.
- Central apnea: CNS immaturity or effects of medications or illness → absent both the airflow and chest wall motion.
- Mixed apnea (both central and obstructive apnea).

Etiology

- Idiopathic apnea of prematurity: infants usually <34 wks' gestation, weighing <1,800 gm & have no other identifiable cause. Usually resolves by 36-37 wks' corrected age.
- Pathological apnea: it has variable etiologies (**Table 18-4**).

Table (18-4): Potential Causes of Pathological Apnea

Neurological	IVH, perinatal asphyxia, meningitis, cerebral infarction, seizures
Respiratory	Hypoxia, airway obstruction, severe RDS, pneumonia, pneumothorax, inadequate ventilation or too early extubation
Infections	Sepsis
Gastrointestinal	NEC, gastroesophageal reflux, feeding intolerance
Metabolic	Hypoglycemia, hypocalcemia, hyponatremia or hypernatremia, hyperammonemia, acidosis, hypothermia
Cardiovascular	Hypotension, heart failure, PDA, congenital heart block
Hematological	Anemia or polycythemia
Drugs	<ul style="list-style-type: none"> • Prenatal exposure (transplacental transmission): narcotics, β-blockers • Postnatal exposure: sedatives, prostaglandin E₁

Clinical Manifestations

- Assess & monitor all neonates at high risk for apneic spells for at least the first week after birth; thorough physical and neurological examination rules out apparent abnormalities.
- Observe and document apneic/bradycardic spells and any relationship to precipitating factor.

Investigations

- CBC with differential
- Serum electrolyte, calcium and glucose levels
- Blood gas analysis
- Chest x-ray, cranial sonar and brain CT scan may be required

Management

- Begin with tactile stimulation for mild self resolving apneas and give supplemental O₂ by nasal cannula (0.5-2 liter/min) or head box. If no response, use bag and mask ventilation during the spell.
- Avoid apnea triggering maneuvers (e.g., suctioning, oral feedings).
- Give packed RBC transfusion, if Hct <35%, with frequent and severe apneic spells.
- Treat the identified cause.
- Pharmacological (Xanthine) therapy
 - ▶ Theophylline: loading dose (6 mg/kg/IV) followed 8 hrs later by maintenance dose (2 mg/kg q8 hrs)
 - ▶ Caffeine citrate: loading dose (20 mg/kg PO or IV over 30 min), followed 24 hrs later by maintenance (5-8 mg/kg PO or IV q24 hrs)
- If no apneic spells have occurred for 5-7 days, discontinue treatment at 34-36 wks' corrected age.
- Continue monitoring until no apnea has been detected for at least 5 days after that period.
- NCPAP: if infant continues to have apnea while on theophylline.
- Mechanical ventilation: if other measures are unsuccessful.

CHAPTER 19

Blood Gas Interpretation

Acidosis

Acidosis is a downward shift in pH <7.35 . It is either metabolic acidosis or respiratory acidosis.

Alkalosis

Alkalosis is an upward shift in pH >7.45 . It is either metabolic alkalosis or respiratory alkalosis.

Anion gap

Serum $(\text{Na}^+) - (\text{Serum } [\text{Cl}^-] + \text{Serum } [\text{HCO}_3^-])$ (normal: 8-16 mEq/L).

Normal Arterial Blood Gas Values

- pH: 7.35-7.45
- PaCO_2 : 35-45 mmHg
- HCO_3^- : 22-26 mEq/L
- Base excess/base deficit: (-4)-(+4)
- paO_2 : 60-80 mmHg
- O_2 saturation 92-94%

N.B.: Venous samples can be used to assess ventilation and acid base status but not oxygenation.

Parameters Used for Diagnosis of Acid Base Disorders

- Type: acidosis or alkalosis (by pH)
- Cause: metabolic or respiratory (by PaCO_2 and bicarbonate)
- Response: uncompensated or compensated
- Duration: acute or chronic
- Form: simple or mixed

Forms of Acid-base Disorders

Simple acid-base disorders = one primary abnormality and its compensatory mechanism

Mixed acid-base disorders = a combination of simple acid-base disturbances (should be considered when the expected compensation falls out of the expected range).

Acid-base Nomogram (Figure 19-1)

It can aid in diagnosing simple & mixed acid-base disorders.

N.B.: Results of blood gases should be correlated to the infant's clinical status.

Table (19-1): Expected Compensatory Mechanisms Operating in Primary Acid-base Disorders

Acid-Base Disorder		Primary Event	Compensation	Rate of Compensation
Metabolic Acidosis	normal anion gap	HCO_3^- Loss	$\downarrow \text{PCO}_2$	For $\downarrow 1$ mEq/L in $\text{HCO}_3^- \rightarrow$ $\downarrow \text{PCO}_2$ by 1-1.5 mmHg
	\uparrow anion gap	\uparrow acid production \uparrow acid intake		
Metabolic Alkalosis		$\uparrow \text{HCO}_3^-$	$\uparrow \text{PCO}_2$	For $\uparrow 1$ mEq/L in $\text{HCO}_3^- \rightarrow$ $\uparrow \text{PCO}_2$ by 0.5-1 mmHg
Respiratory Acidosis	Acute <12-24 hrs	$\uparrow \text{PCO}_2$	$\uparrow \text{HCO}_3^-$	For $\uparrow 10$ mmHg in $\text{PCO}_2 \rightarrow$ $\uparrow \text{HCO}_3^-$ by 1 mEq/L
	Chronic 3-5 days			For $\uparrow 10$ mmHg in $\text{PCO}_2 \rightarrow$ $\uparrow \text{HCO}_3^-$ by 4 mEq/L
Respiratory Alkalosis	Acute <12 hrs	$\downarrow \text{PCO}_2$	$\downarrow \text{HCO}_3^-$	For $\downarrow 10$ mmHg in $\text{PCO}_2 \rightarrow$ $\downarrow \text{HCO}_3^-$ by 1-3 mEq/L
	Chronic 1-2 days			For $\downarrow 10$ mmHg in $\text{PCO}_2 \rightarrow$ $\downarrow \text{HCO}_3^-$ by 2-5 mEq/L

N.B.: The Winters' formula can be used to predict the appropriate respiratory response (decrease in PCO_2) to a metabolic acidosis: $[PaCO_2 = (1.5 \times HCO_3^-) + 8 \pm 2]$.

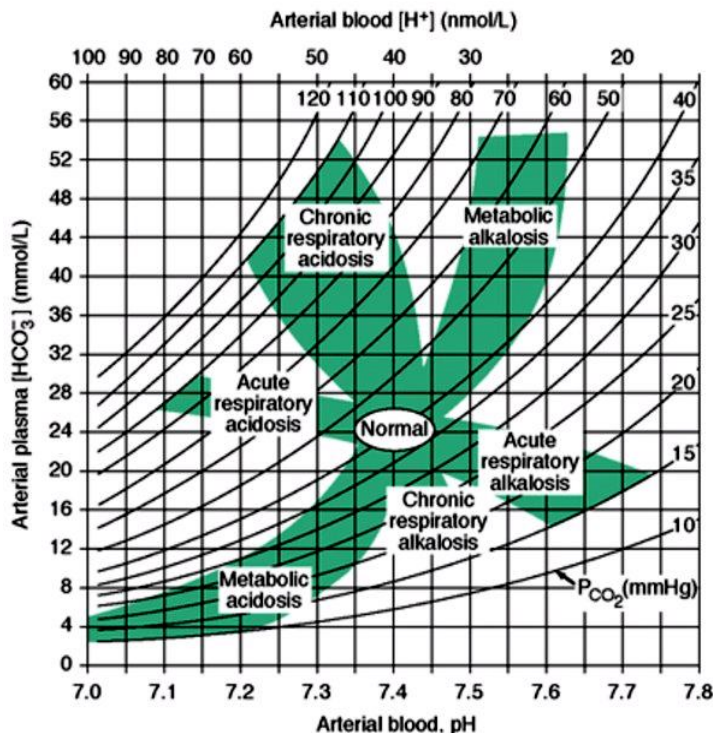


Figure (19-1): Acid-base nomogram [depending on pH, PCO_2 and serum bicarbonate (HCO_3^- mmol/L = mEq/L)].

Reprinted with permission from DuBose Jr, TD. Acid base disorders. In: Brenner and Rector's. The Kidney, 6th Ed, Brenner BM (ed.). Philadelphia, Saunders 2000: 925-997.

CHAPTER 20

Oxygen Therapy

Methods for Oxygen Delivery

Nasal cannula (nasal prongs)

- Provides low-to-moderate O_2 concentrations (22-55%) at flow rates (0.5-2 liter/min). Delivered O_2 should be warm and humidified.

Head boxes (oxyhood)

- It may provide high concentrations of O_2 (>60%).
- The head box should be of an appropriate size (enough to cover the infant's head while allowing the infant to move).
- Adjust flow rate at 6-10 liter/min (not <4 liter/min).
- Place a thermometer in the head box; the temperature inside should be maintained within the infant's NTE range.

Incubator

- Oxygen concentration can be measured by an oxygen analyser (placed near baby's head and calibrated each shift).
- Usually used during oxygen weaning.

Simple face mask

- It delivers an FiO_2 of 35-55% at flow rate 6-10 liter/min.

Venturi mask (air-entrainment mask)

- It is designed to deliver specific oxygen concentrations.

Compressed Air

If an oxygen blender is not available we may blend compressed air with oxygen by using 2 flowmeters; one for compressed air and the other for oxygen, and the required O_2 concentration can be calculated according to (Table 20-1).

Table (20-1): Oxygen Concentrations for Air and Oxygen Mixtures

% O ₂ Conc.		Compressed Air (liters/minute)									
		1	2	3	4	5	6	7	8	9	10
Oxygen (liters/minute)	1			41%	37%	34%	32%	31%	30%	29%	28%
	2		61%	53%	47%	44%	41%	38%	37%	35%	34%
	3	80%	68%	61%	55%	51%	47%	45%	43%	41%	39%
	4	84%	74%	66%	61%	56%	52%	50%	47%	45%	44%
	5	86%	77%	70%	65%	61%	57%	54%	51%	49%	47%
	6	88%	80%	74%	68%	64%	61%	57%	54%	53%	51%
	7	90%	82%	76%	71%	67%	64%	61%	58%	56%	54%
	8	91%	84%	78%	74%	70%	66%	63%	61%	58%	56%
	9	92%	86%	80%	76%	72%	68%	65%	63%	61%	58%
	10	93%	87%	82%	77%	74%	70%	67%	65%	63%	61%

Monitoring of Oxygen Therapy

Oxygen therapy & infant's oxygenation must be closely monitored.

- Pulse oximetry: target SaO₂ should be based on the infant's GA and clinical judgment (**Table 20-2**).

Table (20-2): Target SaO₂ & PaO₂, Based on the Infant's GA

Infants	PaO ₂	SaO ₂ range*
Preterm <32 wks' gestation	50-70 mmHg	87-92%
Preterm ≥32 wks' gestation	60-75 mmHg	90-93%
Term/post-term	60-90 mmHg	90-95%

*For infants who are in air and do not need supplemental oxygen, saturations that are mostly above 90% are regarded as satisfactory.

N.B.: FiO₂ should be titrated to the lowest concentration required to meet oxygenation goals.

Chapter 20: Oxygen Therapy

- Arterial blood gas analysis: it measures PaO_2 ; UAC is used in VLBW infants or infants likely to have prolonged course; in other infants, radial or posterior tibial arteries may be used.
- Capillary blood gas analysis: it gives an indication of pH and PCO_2 only, and is not useful for PaO_2 assessment.

Documentation

- Document O_2 concentration in percentage or liter-flow/ min, method of delivery and water temperature hourly on the Daily Neonatal Clinical Record.
- All adjustments made based on the neonate's status and/or physician orders must be noted.

Oxygen Therapy Equipment Changes

- Nasal prongs should be changed once/week, or in between if blocked with nasal secretions.
- Oxygen masks/portable oxygen analysers & SaO_2 probes are changed when baby is discharged.

Oxygen Toxicity and Complications (Refer to Chapter 23)

CHAPTER 21

Continuous Positive Airway Pressure (CPAP)

Methods of Application

- Nasal prongs (Nasal CPAP)
- Nasopharyngeal tubes (Nasopharyngeal CPAP)
- Endotracheal tubes (Endotracheal CPAP)
- Face mask (Face Mask CPAP)

N.B.: Prolonged endotracheal CPAP should not be used.

Indications of CPAP

- Mild to moderate RDS (minimal respiratory distress and minimal need for oxygen): start CPAP immediately after the onset of respiratory distress or even prophylactically at birth to extremely preterm infants
- Infants with TTN
- Infants with MAS
- Preterm infants with moderately frequent apneic spells
- Infants who have been weaned from a mechanical ventilator
- Infants with airway diseases (e.g., tracheomalacia)
- Infant with paralysis of the diaphragm
- Post operative (e.g., exomphalos, gastroschisis, CHD & thoracic surgery)

Criteria for Starting Nasal CPAP

- Inability to maintain a PaO_2 of 60 mmHg with an FiO_2 of 0.6 in infants with RDS.
- Consider NCPAP if an infant has any of the following:
 - ▶ $\text{RR} > 60$ breaths/min
 - ▶ Moderate to severe grunting

- ▶ Respiratory retraction
- ▶ Oxygen saturation <93% (preductal)
- ▶ Frequent apnea
- Nasal CPAP can be given prophylactically even in the delivery room to extremely preterm babies; also it can be given after short intubation and surfactant instillation.

Contraindications of NCPAP

- The need for MV because of respiratory failure
- Unstable respiratory drive with frequent apneas or bradycardias not improved by CPAP
- Upper airway anomalies (e.g., cleft palate, choanal atresia, tracheoesophageal fistula)
- Untreated congenital diaphragmatic hernia
- Severe cardiovascular instability

Methods of Generating Continuous Positive Pressure

- Bubble or water-seal CPAP: by immersion of the distal expiratory tubing in sterile water to the desired depth.
- Ventilator-derived CPAP: by adjusting a CPAP valve.
- Continuous pressure is generated at the airway proximal to the infant's nares (generator).

Application of CPAP (Bubble CPAP)

Preparing the system

- Adjust the blender to the appropriate FiO_2 .
- Turn on the flowmeter (5-10 liters/min), depending on the infant's size.
- Fill the humidifier container with sterile water up to the correct mark, turn on the humidifier, adjust humidification, and set the temperature at 36°C .
- Fill the bottle up to the correct mark with sterile water. Put the distal expiratory end of the corrugated tube in the bottle to the desired level (i.e. 5 cmH_2O).

- Choose the correct size prongs and connect them to the free ends of both of the corrugated tubes. The correct size prongs should fit the nares without pinching the septum.
- General guidelines for the correct size prongs are:
 - ▶ Size 2 for weight 1,000-2,000 gm
 - ▶ Size 3 for weight 2,000-3,000 gm
 - ▶ Size 4 for weight 3,000-4,000 gm
 - ▶ Size 5 for weight >4,000 gm
- Occlude the ends of the nasal prongs to test integrity of the circuit, and observe bubbling in the bottle.

Attaching the system to the infant

- Position the infant with the head of the bed elevated 30°.
- Gently suction the infant's mouth, nose, and pharynx. Use the largest sized catheter that can be passed into the nose without significant resistance. Make sure the infant does not have choanal atresia.
- Place a small roll under the infant's neck/shoulder.
- Moisten the prongs with sterile water or saline drops before placing them.
- Ensure a small space between the tip of the septum and the bridge between the prongs.
- Pass an orogastric tube and aspirate the stomach contents. You can leave the tube in place to avoid gastric distension.
- Use an appropriate sized hat (bonnet).
- Start CPAP at a pressure of 5 cmH₂O to be increased by 1-2 cmH₂O increments if necessary (to a maximum of 8 cmH₂O) based on the clinical response and the O₂ requirements.
- Once the system is applied, check that the prongs are positioned appropriately and that the system is bubbling.

Maintaining NCPAP

- Follow the infection control guidelines.

Chapter 21: Continuous Positive Airway Pressure (CPAP)

- Check vital signs every 2-4 hrs.
- Ensure that infant's nose is in a normal position (i.e., not pushed upwards), his/her eyes are clearly visible and the ears are not folded.
- Suction nasal cavities, mouth, pharynx & stomach, as needed:
 - ▶ ↑Respiratory effort, ↑need for O_2 , and the occurrence of apnea/bradycardia may be indications for suctioning.
 - ▶ Use the largest size suction catheter able to pass without significant resistance.
 - ▶ Note the amount, consistency & color of the secretions.
 - ▶ Use a few drops of sterile saline to loosen dry thick secretions.
- Change the infant's position every 4-6 hrs.
- Agitation can be reduced by nesting, decreasing environmental light & sound stimuli, and minimal handling of the infant.
- Change CPAP circuits weekly.

Indicators of Improvement

- Clinical
 - ▶ Decreasing work of breathing
 - ▶ Improving infant's condition
- Blood gas analysis
 - ▶ ↓ or stabilization of O_2 requirements at $FiO_2 < 0.3$ with $PaO_2 > 50$ mmHg (between 60-80 mmHg) or SaO_2 between 90-93%
 - ▶ Maintenance of adequate ventilation: $PaCO_2 < 60$ mmHg (permissive hypercapnia with upper limit of CO_2 up to 65 mmHg can be allowed) & pH 7.25-7.45
- Radiological
 - ▶ Improved lung volume & appearance on chest x-ray films.

Weaning from CPAP

- Lower FiO_2 gradually in decrements of 2-5% as guided by the pulse oximeter reading or by the blood gas results. The requirement of FiO_2 usually comes down to room air.

- Give a trial off of CPAP if the infant is breathing comfortably on CPAP with an FiO_2 of 21%:
 - ▶ The nasal prongs should be separated from the corrugated tubing while the tubing is kept in place.
 - ▶ A series of trials off CPAP is usually required before the infant can be weaned off completely.
 - ▶ During the trial off CPAP, assess the infant for any tachypnea, retractions, oxygen desaturation, or apnea. If any of these signs are observed, the infant should be restarted immediately on CPAP for at least a day before another trial is attempted.
- If infants are considered ready for a trial off CPAP, ensure that conditions are optimal (e.g., no severe anemia, no symptomatic PDA or early sepsis), if necessary caffeine or aminophylline may be used.
- While off CPAP, supplemental O_2 can be given, as needed.
- For a period of 12-24 hrs after coming off from the CPAP, infants will usually require nasal and oral suctioning at least as frequently as for the previous 24 hrs.

N.B.: Fast weaning in an infant who requires a high FiO_2 and is clinically unstable will be associated with weaning failure.

Feeding with NCPAP

It may be necessary to aspirate excess air from the stomach before feeds. If clinically stable, infants may be breastfed, bottle, or tube-fed. An orogastric tube is preferable.

CPAP Failure (Indications for MV)

- $\text{PaO}_2 < 50$ mmHg while breathing 60-80% oxygen
- Respiratory acidosis ($\text{pH} < 7.20$ - 7.25 , or $\text{PaCO}_2 > 60$ - 65 mmHg)
- Persistent hypoxemia and metabolic acidosis with a base deficit of > -8
- Marked retractions observed while on CPAP
- Intractable apnea and bradycardia

Troubleshooting during NCPAP

The bottle is not bubbling (due to an air leak in the circuit)

- Remove the prongs from the nose and occlude them; if the system bubbles, the size of prongs is not correct.
- If the infant opens his/her mouth, ensure mouth closure using a pacifier or placing a chin strip. Avoid using adhesive strapping of the mouth (fear of aspirating gastric contents).
- Systematically check each component of the circuit.

The prongs do not stay in place

Check for the following:

- Are the prongs the right size?
- Does the hat fit snugly?
- Are the corrugated tubes fixed correctly to the hat on both sides and at the correct angle to the prongs?

The infant is not settling down

- Check for airway secretions.
- Use a pacifier and swaddle the infant.
- Aspirate excess gas from the stomach, if necessary.

Nasal injury

- Ranges from mild (edema or erythema) to severe (nasal snubbing, flaring of nostrils, or septal damage).
- Prevention is the key strategy
 - ▶ Use the correct sized prongs.
 - ▶ Moisten the prongs with sterile water or saline before placing them. Do not use any gels, creams, or ointment.
 - ▶ Ensure appropriate fit of the prongs to infant's nose.
 - ▶ Do not allow the bridge of the prongs to touch the nasal septum at any time.
 - ▶ If the nose looks red & tender, use Duoderm under the prongs.

Abdominal distension (CPAP belly syndrome)

- A benign condition and is not a contraindication to feeding.
- It can be minimized by routine use of orogastric tube and suctioning the air accumulated in the stomach by syringe every 3-4 hrs, or leaving the orogastric tube venting.

Pulmonary air leaks

- May occur when oxygen requirements are decreasing and lung compliance is improving.

CHAPTER 22

Assisted (Mechanical) Ventilation

Parameters of MV

Peak inspiratory pressure (PIP)

- Adjust PIP initially to achieve adequate tidal volume (V_t), as reflected by chest excursion and adequate breath sounds.
- PIP up to 25 cmH_2O in preterm and up to 30 cmH_2O in full term may be required in infants with decreased lung compliance.
- Decrease PIP gradually with improvement of lung disease down to 10-12 cmH_2O .
- Too low PIP $\rightarrow \downarrow V_t \rightarrow$ hypoxia
- Too high PIP $\rightarrow \uparrow V_t \rightarrow$ barotraumas, BPD and \downarrow venous return

Positive end expiratory pressure (PEEP)

- PEEP can be adjusted as low as 3 cmH_2O & as high as 8 cmH_2O (moderate PEEP = 4-6 cmH_2O).
- High PEEP ($>8 \text{ cmH}_2\text{O}$) $\rightarrow \downarrow V_t$, \downarrow venous return, air leaks & CO_2 retention
- Ventilated newborn should have a minimum physiologic PEEP of 2-3 cmH_2O .
- Inadvertent PEEP: the chosen PEEP may be increased if the expiration time is too short or airway resistance is increased \rightarrow gas trapping & increase risk of air leak.

Fraction of inspired oxygen (FiO_2)

- The simplest means of improving oxygenation.
- FiO_2 is adjusted to maintain an adequate oxygenation; it can be as low as 21% and as high as 100%.

Rate (RR) or frequency/minute

- Adjust RR according to the GA & the underlying disease.
- RR 40-60 breaths/min is usually sufficient in most of cases; it can be decreased to 20 breaths/min during weaning.
- Increasing RR, while keeping the T_i the same → air trapping.

Inspiratory time (T_i)

- Adjust between 0.35-0.6 second depending on the pulmonary condition.

Inspiratory time (T_i)/expiratory time (T_e) ratio (I:E Ratio)

- I:E ratio should not be <1:1.2 and should not be reversed.

Flow Rate [volume of gas passed/time unit (liter/minute)]

- Flow rates of 6-10 liters/min are sufficient in most cases.
- Low flow rate → effective PIP will not be reached
- High flow rates → barotraumas

Mean air way pressure (MAP)

- MAP will be augmented by ↑PIP, PEEP, T_i & flow rate
- Adjust MAP between 10-12 cmH₂O; higher levels are associated with an increased risk of air leaks.

Indications for MV**Absolute indications**

- Severe hypoxemia (PaO_2 <50 mmHg despite FiO_2 of 0.6-0.8)
- Respiratory acidosis (pH <7.20-7.25, $PaCO_2$ >60-65 mmHg)
- Intractable apnea/bradycardia

Relative indications

- Frequent intermittent apnea unresponsive to drug therapy or NCPAP
- When use of MV is anticipated (deteriorating gas ex-change).
- Relieving work of breathing in infants with respiratory distress.
- Initiation of exogenous surfactant therapy in infants with RDS.

Initiation of MV

ET intubation

Intubate the infant orally with an ETT according to the guidelines (**Refer Chapter 2**); the tip of the tube should be located 1-2 cm above the carina and chest x-ray should be done.

Initial settings of MV (according to the disease)

Respiratory distress syndrome (RDS)

Most infants with RDS tolerate high rates and short expiratory times without marked gas trapping and inadvertent PEEP.

- FiO_2 : 0.4-0.6
- Low PIP (estimated by good chest excursion): usually 12-20 cmH_2O
- PEEP: 4-5 (up to 6) cmH_2O
- Flow rates: 6-8 liters/min
- Rapid Rate: >60 breaths/min
- Ti : 0.2-0.3 second (rarely, longer Ti required to provide adequate oxygenation).
- I:E ratio: not less than 1:1.2 and not to be reversed

Meconium aspiration syndrome (MAS)

Care must be taken to set the ventilator Ti & rates that permit adequate inspiration to deliver the required Vt & adequate expiration to avoid inadvertent PEEP.

- High PIP: 25-30 cmH_2O
- Moderate PEEP: 4-5 cmH_2O
- Moderate rate: 40-60 breaths/min
- I:E ratio >1:3 (prolonged expiration)
- If gas trapping occurs, decrease PEEP & increase expiratory time.
- Sedation or muscle relaxation may be required

Air leak

The primary goal is to reduce MAP through any of its components (PIP, Ti , PEEP) and to rely on increased FiO_2 to provide oxygenation.

- Low PIP
- Short Ti
- Low PEEP
- RR may be increased up to 60 breaths/min
- High FiO₂

Apnea

For infants completely dependent on the ventilator, the goal should be to provide physiologic ventilation using:

- FiO₂: 0.21-0.3
- PIP: 10-18 cmH₂O
- PEEP: 3-4 cmH₂O
- Rates: 30-40 breaths/min
- Ti: 0.35-0.4 seconds
- Flow rate: 7-8 liters/min

For an infant requiring a ventilator because of intermittent but prolonged apnea, low rates (20 breaths/min) may be sufficient.

Subsequent Settings of Mechanical Ventilation

Measure arterial blood gases, 30 min after the initial setting & adjust the setting accordingly (Table 22-1), (Table 22-2).

Table (22-1): Principles of Adjusting Oxygenation and Ventilation

Change Oxygenation (PaO₂)	Change FiO ₂ - Change MAP
Change Ventilation (PaCO₂)	Change Vt - Change RR

MAP: mean airway pressure, Vt: tidal volume, RR: respiratory rate

Table (22-2): Change of Ventilator Parameters According to Desired Blood Gases

Desired goal	PIP	PEEP	Rate	Ti
Decreased PaCO ₂	↑	↓	↑	↓
Increased PaCO ₂	↓	↑	↓	↑
Increased PaO ₂	↑	↑	–	↑
Decreased PaO ₂	↓	↓	–	↓

Paralysis and Sedation

- Not routinely indicated.
- If the infant is fighting the ventilator, sedation using midazolam, phenobarbital and fentanyl or paralysis with pancuronium can be used (volume expanders may be required, because paralysis results in 3rd spacing of fluid).

Physiotherapy and Suctioning

- Physiotherapy and suctioning should be done to prevent the atelectasis, especially in premature infants.
- Continuously monitor SaO₂ by pulse oximetry.
- During suction, the catheter **should not** be inserted beyond the lower end of the ETT.
- During accompanying ambu-bagging (manual ventilation), FiO₂ may be increased by 10% over the infant's current requirement.
- Unless there is evidence of a beneficial effect, minimum handling of fragile preterm infants should be followed.

Monitoring the Infant on MV

- Obtain an initial blood gas within 30 min of starting MV.
- Obtain a blood gas within 30 min of any change in ventilator settings.
- Obtain a blood gas q6 hrs unless a sudden change in the infant's condition occurs.
- Continuously monitor SaO₂, HR & RR.
- Maintain SaO₂ between 87-93% in preterm infants.

Deterioration during MV (Table 22-3)

Table (22-3): Deterioration of an Infant during MV

Sudden Deterioration	Gradual Deterioration
<ul style="list-style-type: none"> • Mechanical or electrical ventilator failure • Disconnected tube or leaking connection • ETT displacement or blockage • Pneumothorax 	<ul style="list-style-type: none"> • Inappropriate ventilator setting • Intraventricular hemorrhage • Patent ductus arteriosus • Anemia • Pulmonary interstitial emphysema • Infection/pneumonia

Weaning from MV

When to wean?

- If the infant is clinically stable as evidenced by decreased work of breathing, increased chest expansion and aeration by chest auscultation, and radiographic evidence of improved lung volume.
- If the infant has an efficient spontaneous respiratory drive.
- If the infant is able to maintain satisfactory blood gases:
 - ▶ $\text{PaO}_2 > 50$ mmHg
 - ▶ Optimal PaCO_2 varies according to disease state. For very immature infants or infants with air leaks, a PaCO_2 of 50-60 mmHg may be tolerated “permissible hypercarbia”, provided that pH is > 7.25 .

Principles

- Decrease the most potentially harmful parameter first (FiO_2 & PIP).
- Limit changes to one parameter at a time.
- Avoid changes of large magnitude.
- Follow-up blood gas after each change.

Steps

- \downarrow PIP as tolerated and as noted by adequate chest rise.
- When PIP is around 20, \downarrow FiO_2 , and then the RR alternating with each other, in response to assessment of chest excursion, blood gas results and SaO_2 .
- If Assist/Control (A/C) mode is used, switch to SIMV when $\text{FiO}_2 < 0.4$ and $\text{PIP} < 12$ cmH₂O.

Chapter 22: Assisted (Mechanical) Ventilation

- Decrease the number of ventilator breaths progressively while the infant steadily increases his spontaneous breathing.
- For infants weighing <1,750 gm, when PIP <12 cmH₂O, FiO₂ <0.3 & RR 20 breaths/min, wean directly to nasal CPAP, if available. Larger infants can be weaned to nasal prongs or to head box.

Extubation

- Provide an FiO₂, as needed.
- Begin with postural drainage and suctioning.
- Connect the ETT to the ambubag and give a prolonged sigh of 15-20 cmH₂O to the infant while the ETT is extracted.
- Follow the infant by pulse oximeter.
- Do a chest x-ray 2 hrs after extubation.
- If the infant is stable, resume feeding 4 hrs after extubation.
- Steroids are not routine before extubation (if prolonged intubation or previous failed attempts of extubation, give dexamethasone 0.25 mg/kg/dose q12 hrs beginning 48 hrs before extubation, as well as aminophylline).
- If stridor (laryngeal edema) develops after extubation, racemic epinephrine aerosols and steroids may be helpful.
- Tracheostomy must be considered if the baby cannot be extubated for at least 4 times over several weeks.

Complications of MV

- ETT complications: accidental displacement (into main stem bronchus, hypopharynx, or esophagus), accidental extubation, or obstruction.
- Airway injury: subglottic stenosis, edema of the cords (hoarseness and stridor), palatal groove (with prolonged orotracheal intubation), and necrotizing tracheobronchitis.
- Pneumonia, infections, BPD/oxygen toxicity.
- Air leak syndromes (related to ↑MAP (>14 cmH₂O)).
- Miscellaneous (IVH, ↓cardiac output, feeding intolerance).

CHAPTER 23**Complications of Oxygen Therapy****Bronchopulmonary Dysplasia**

BPD is defined as a need for supplemental O₂ at 28 days or 36 wks' postconceptional age for infants <32 wks' GA.

BPD occurs frequently in infants <32 wks' GA. However, it may occur in full-term infants with MAS, pneumonia, and certain anomalies that require chronic ventilator support.

Risk Factors

Oxygen toxicity, MV, infection, nutritional deficiency (vitamin A deficiency), excessive fluid administration and PDA, and family history of atopic disease

Clinical Manifestations

- Infants are often extremely immature and have very low birth weights. Their requirements for O₂ and ventilatory support often increase in the first 2 weeks of life. At 2-4 wks' PNA, O₂ supplementation, ventilatory support, or both are increased to maintain adequate ventilation and oxygenation.
- Examination reveals tachypnea, tachycardia, ↑work of breathing, frequent desaturations, wheezing or prolonged expiration. Right-sided heart failure may occur in severe cases.

Investigations

- Blood gas analysis may show hypoxemia and hypercarbia.
- Chest x-ray: radiographic findings may be quite variable
 - ▶ Early: diffuse haziness and hypoinflation with small round radiolucencies dispersed throughout the lungs.

- ▶ Later: streaky interstitial densities, patchy atelectasis, and cyst formation with concomitant hyperinflation.

Treatment

Respiratory support

A) Mechanical ventilation

- Early CPAP application in extremely preterm infants and early weaning from PPV to CPAP.
- Ventilator adjustments are made to minimize MAP and V_t while providing adequate gas exchange
 - ▶ Apply the lowest PIP with the least V_t (no more than 6 ml/kg) necessary to obtain adequate ventilation, using Ti between 0.3-0.5 seconds.
 - ▶ Allow permissive hypercarbia by keeping $PaCO_2$ between 50-65 mmHg and an arterial pH of >7.25 .
- Weaning has to be gradual. When the infant can maintain an acceptable PaO_2 and $PaCO_2$ with low PIP ($<12-15$ cmH $_2$ O) and $FiO_2 < 0.30-0.40$, reduce the rate gradually.
- Aminophylline or caffeine can be used in small infants during weaning.
- When the infant is able to maintain acceptable blood gas levels for several hours on low ventilator rates (15-20 breaths/min), extubation should be attempted.
- Provide chest physiotherapy after extubation.
- In smaller infants, the use of NCPAP after extubation can reduce the need to re-institute MV.

B) Supplemental oxygen

- Provide the least required oxygen.
- Maintain a PaO_2 between 55-80 mmHg.
- Monitor and maintain SaO_2 between 90-95%.

PDA management

- Early management of a hemodynamically significant PDA.

Fluid management

- Restrict fluid to ≤ 130 ml/kg/day (to maintain urine output at least 1 ml/kg/hr and serum Na^+ level of 140-145 mEq/L).
- Later, when respiratory status is stable, fluid restriction is gradually released.

Diuretics

- Furosemide (0.5-1 mg/kg/dose IV, 1-2 times daily)
- Chlorothiazide (20-40 mg/kg/day orally, divided q12 hrs)
- Chlorothiazide (20 mg/kg/day) + spironolactone (2 mg/kg/day)

Bronchodilators

- Albuterol: 0.02-0.04 ml/kg (up to 0.1 ml total) in 2 ml NS, nebulized as needed q6-8 hrs in acute exacerbations.
- Ipratropium bromide: 75-175 μg in 3 ml NS via nebulizer q8 hrs.
- Albuterol + ipratropium bromide
- Theophylline

Corticosteroids

- Routine use of dexamethasone is not recommended unless severe pulmonary disease exists.
- Start at 0.2-0.3 mg/kg/day divided q12 hrs for 48 hrs, then halve the dose q48 hrs and limit the course to <7-10 days.
- Inhaled beclomethasone (100-200 μg 4 times/day).

Nutritional support

- Provide protein and fat supplementation (3-3.5 gm/kg/day); trace minerals are needed.
- Give vitamin A supplementation (5,000 units 3 times/wk for the first 28 days of age).
- Early enteral feeding of small amounts followed by slow, steady increases in volume appears to optimize tolerance of feeds and nutritional support. Breast milk is preferred.
- Infants have high caloric needs (≥ 120 -150 kcal/kg/day).

Blood transfusions

- Maintain Hct \approx 30-35%, as long as O₂ is needed.
- Give furosemide immediately following the transfusion.

N.B.: Prevention of BPD is the cornerstone of management by avoiding factors that predispose to injury.

Retinopathy of Prematurity

Infants with a birth weight <1,500 gm or GA <32 wks and selected infants with a birth weight between 1,500-2,000 gm or GA >32 wks with an unstable clinical course (e.g., those requiring cardiorespiratory support) should have retinal screening examinations performed after pupillary dilation using indirect ophthalmoscopy to detect ROP.

Table (23-1): Suggested Schedule for the Timing of the Initial Eye Examinations to Detect ROP

Gestational Age at Birth (weeks)	Age at Initial Examination (Weeks)	
	Postmenstrual	Chronologic
25	31	6
26	31	5
27	31	4
28	32	4
29	33	4
30	34	4
31*	35	4
32*	36	4

*If necessary

Examination should continue every 2 wks until retina becomes mature; infants with ROP should be examined every 1-2 wks to monitor progression of the disease.

Prevention: careful monitoring of O₂ levels in preterm infants (keep SaO₂ between 87-93%).

CHAPTER 24

Neonatal Sepsis

Neonatal sepsis is a systemic response to infection documented by a positive blood culture in the first month of life.

Types

Table (24-1): Characteristics of Neonatal Sepsis

	Early Onset (<7 days)	Late Onset (≥ 7 days to 3 months)	Very Late Onset (>3 months)
Intrapartum Complications	Often present	Usually absent	Varies
Transmission	Vertical; organism often acquired from mother's genital tract	Vertical or through postnatal environment	postnatal environment, caused by <i>Candida</i> species or by commensal organisms, such as CONS
Clinical Manifestations	Fulminant course, multisystem involvement, pneumonia common	Insidious or acute, focal infection, meningitis common	Insidious, affects VLBW infants in NICU, and usually is associated with prolonged instrumentation
Case-Fatality Rate	5-20%	5%	Low

CONS: coagulase negative staphylococci, VLBW: very low birth weight

Etiology

Table (24-2): Risk Factors for Neonatal Sepsis*

Maternal Factors	Neonatal Factors	LOS in VLBW infants
<ul style="list-style-type: none"> • Maternal UTI • Intrapartum fever >37.5°C • Preterm labor • ROM ≥18 hrs • Chorioamnionitis • GBS colonization • Pregnancy on intrauterine device or with cervical circlage 	<ul style="list-style-type: none"> • Prematurity • LBW (<2,500 gm) • Perinatal asphyxia • Multiple gestations • ETT, central lines, • Formula-feeding • Congenital immune defects or asplenia • Galactosemia • Obstructive uropathy • Abuse of antibiotics 	<ul style="list-style-type: none"> • Birth weight <750 gm • Central catheters • Delayed enteral feeding • Prolonged TPN • Mechanical ventilation • PDA, BPD • NEC

* Other factors include a high nurse-infant ratio in the NICU

LOS: late onset sepsis, UTI: urinary tract infection, ROM: rupture of membranes, GBS: group B streptococci, TPN: total parenteral nutrition

Causative organisms

Bacterial infections

Table (24-3): Common Bacteria Responsible for Sepsis

Early Onset Sepsis	Late Onset Sepsis
<ul style="list-style-type: none"> • Gram-negative enteric bacilli (e.g., <i>E.coli</i>, <i>Klebsiella</i> species) • <i>Enterococci</i> • Coagulase-negative Staphylococci (CONS) • Group B streptococci (GBS) 	<ul style="list-style-type: none"> • Coagulase-negative staphylococci (CONS) • <i>Staphylococcus aureus</i> (MRSA) • Gram-negative enteric bacilli • Group B streptococci (GBS)

Fungal (*Candida* & other fungi)

Viral infections (adenovirus, enterovirus, coxsackievirus, HSV)

Clinical Manifestations

- Physical findings may be nonspecific and subtle.

- Clinical manifestations may include:
 - ▶ Respiratory distress (ranges from tachypnea and grunting to respiratory failure) is the most common symptom, particularly in EOS
 - ▶ PPHN
 - ▶ Lethargy, poor reflexes & irritability
 - ▶ Hypothermia (more common) or hyperthermia
 - ▶ Poor perfusion, hypotension and shock
 - ▶ Poor feeding, vomiting, diarrhea, abdominal distension and ileus
 - ▶ DIC with purpura and petechiae
 - ▶ Hepatomegaly and jaundice
 - ▶ Meningitis without neurologic symptoms or with bulging or full fontanelle, seizures, apnea and ↓ sensorium

Investigations

Laboratory studies

CBC with differential

Its usefulness is improved if a second CBC is obtained.

- Total WBC count: leucopenia (WBC count <5,000)
- Neutropenia: absolute neutrophil count (ANC) <1,500
- Immature: Total neutrophil ratio (I:T ratio): ≥0.2
- Thrombocytopenia: in severely ill infants

C-reactive protein (CRP)

- It is a non specific marker. Serial determinations at 12 hrs intervals after the onset of presumed sepsis increase its sensitivity.
- Infants with onset of infection in the first 12 hrs of life and infants with GBS infection may not have an elevated CRP.
- CRP should not be used alone to diagnose sepsis. It is particularly more important for follow-up.

Cultures

- All cultures should be obtained prior to antibiotic therapy.

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- If culture is positive, repeat it 48 hrs after starting antibiotic therapy to confirm the clearance of the organism.

Blood culture

- Use 2 culture bottles; one aerobic and the other anaerobic.
- Obtaining more than one blood culture may improve the results and can be helpful in distinguishing blood culture contaminants from true pathogens.
- A definitive diagnosis of sepsis can only be made with a positive blood culture.

Urine culture

- Obtain a sterile specimen in all neonates with suspected sepsis (by suprapubic bladder aspiration or catheterization).
- If bagged urine is used for culture, results may be less reliable; in that case, a colony count <10,000 colony forming unit (cfu)/ml indicates contamination, from 10,000-100,000 cfu/ml is suspicious, and >100,000 cfu/ml of a single organism is reliable.

CSF culture

- Lumbar puncture (LP) should be incorporated in the evaluation of any infant with clinical evidence of probable sepsis that is confirmed by the rapid screening tests (CBC, CRP).
- CSF cell count, protein and glucose concentrations, Gram stain and culture should be performed before the antibiotics administration, if the infant is clinically stable.

Local site culture

- Tracheal aspirate culture in intubated infants with a clinical picture suggestive of pneumonia, or when the quality and volume of the secretions change substantially
- Skin wound culture
- Stool culture in sepsis caused by enteric pathogens (e.g., *Shigella*, *Salmonella* & *Campylobacter*)

Serum glucose level

- Hypoglycemia or hyperglycemia

Arterial blood gas analysis

- Metabolic acidosis may be present.
- It should be done for infants with respiratory symptoms.

Evidence of DIC

- Prolonged PT, APTT, and INR, and ↑FDP's.

Imaging studies

- Chest radiography may reveal segmental or lobar infiltrate but more commonly reveals a diffuse, fine, reticulogranular pattern. Pleural effusions may be observed.
- Cranial ultrasonography in infants with meningitis. Serial cranial ultrasonography may be needed to detect the complications such as obstructive hydrocephalus.
- Echocardiography: in severely ill, cyanotic infants to determine PPHN or cardiac failure is present.
- CT scan or MRI may be needed late in the course of meningitis.

Prevention

The most important step in management is prevention by following strict infection control policies in the NICU.

Intrapartum antimicrobial prophylaxis (IAP)

IAP is given to the pregnant women at the time of labor or ROM

Indications of IAP

- Previous infant with invasive GBS disease
- GBS bacteriuria during the current pregnancy
- Positive GBS screening culture during current pregnancy (unless a planned CS, in absence of labor or ROM, is performed)
- Unknown GBS status and any of the following:
 - ▶ Delivery at <37 wks' gestation
 - ▶ ROM ≥18 hrs

- ▶ Intrapartum maternal fever ($\geq 38^{\circ}\text{C}$)

Neonates born to mothers who received IAP

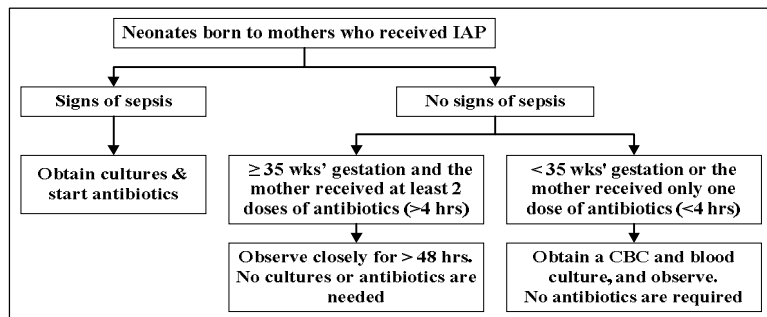


Figure (24-1): Actions taken in neonates born to mothers received IAP

Prophylactic antimicrobial therapy

- Antibiotics should not be used as broad-spectrum coverage against many potential pathogens.
- Prophylactic administration of fluconazole is effective in preventing fungal colonization and invasive fungal infection in VLBW and ELBW infants.

Treatment

Antimicrobial therapy

- Initial (empiric) therapy is most often begun before a definite causative agent is identified.
- Continuing therapy is based on culture and sensitivity results, clinical course & laboratory studies (e.g., CRP).
- Repeat cultures 48 hrs after initiation of therapy; if cultures are still positive and the clinical course is not improved, alteration of therapy may be necessary.

Selection of the appropriate antimicrobial therapy

Early onset neonatal sepsis

- Obtain cultures first.

- Recommended 1st line antibiotics: ampicillin + gentamicin.
- Third generation cephalosporins (cefotaxime or ceftazidime) may be added to gentamicin, if meningitis is clinically suspected or if gram-negative rods are dominant.

Late onset neonatal sepsis

- Generally, staphylococcal coverage with vancomycin + aminoglycoside **or** 3rd-generation cephalosporin.

Anaerobic infection

- Clindamycin

Fungal infection

- Fluconazole for systemic infections, meningitis and severe superficial mycoses caused by *Candida* species.
- Amphotericin B; liposomal preparation is less toxic.
- Remove central catheters to eradicate infection.

Duration of therapy

- Therapy should continue for 10-14 days.
- In cases with meningitis, continue therapy for 14-21 days.
- In cases with UTI, continue therapy for 10-14 days and screen for renal anomalies.

Monitoring of therapy

- All infants receiving aminoglycosides and vancomycin must have serum concentrations monitored.
- Infants with shock or renal compromise should have serum levels monitored after the first dose.

Supportive therapy

- Inotropic agents and volume support for hypotension and poor perfusion
- Fluid and electrolyte therapy
- Enteral or parenteral nutrition, according to the needs
- MV and/or exogenous surfactant for pneumonia and RDS

- Sodium bicarbonate for metabolic acidosis
- Anticonvulsants for seizures

Intravenous immunoglobulin (IVIG)

A single dose (500-750 mg/kg/dose over 2-6 hrs) for seriously ill infants with overwhelming sepsis is an adjunctive therapy.

Focal Bacterial Infections

Cellulitis

- Full term infants: treat localized erythema and/or discharge by careful washing, local antibiotic ointment and monitoring.
- Preterm infants: cellulitis must be promptly discovered and carefully treated. Obtain a CBC and blood culture and administer IV antibiotics (vancomycin and gentamicin).
 - ▶ If blood culture is –ve, continue therapy for 5-7 days with resolution of the cellulitis.
 - ▶ If blood culture is +ve, obtain a lumbar puncture to rule out meningitis, examine the infant to rule out osteomyelitis or septic arthritis, and adjust therapy according to the identified organism.

Omphalitis

- Administer vancomycin + aminoglycoside, or 3rd generation cephalosporin. Add metronidazole in the presence of crepitus or black discoloration of the periumbilical tissues.
- Necrotizing fasciitis requires extensive supportive care and early surgical consultation.

Conjunctivitis

Gonorrheal conjunctivitis

- Frequent irrigation of the conjunctival sac with sterile isotonic saline until the discharge has resolved.
- Ceftriaxone (25-50 mg/kg, IV or IM, not to exceed 125 mg) single dose or cefotaxime (100 mg/kg, IV or IM) single dose.

- Admit and evaluate the infants; for disseminated infection, give ceftriaxone or cefotaxime for 7-14 days.
- Screen for coincident chlamydial infection.

Chlamydial conjunctivitis

- Oral erythromycin, 50 mg/kg/day in 4 doses for 14 days. Evaluate the infant for the need for a 2nd course.
- Topical treatment is ineffective and is not indicated.
- Evaluate for concomitant chlamydial pneumonia.

Other bacterial conjunctivitis

- Local saline irrigation
- Topical antibiotics (ointments or drops) q6 hrs for 7-10 days for other forms of bacterial conjunctivitis
- *Pseudomonal* conjunctivitis requires parenteral treatment (aminoglycoside + antipseudomonal penicillin).

Osteomyelitis and Septic Arthritis

- Initiate empiric parenteral therapy (vancomycin + aminoglycoside or an extended-spectrum cephalosporin).
- Consult orthopedic surgeon.
- When the specific organism has been identified, treatment should be continued with the most appropriate antibiotic.
- Therapy should be continued for 3-4 wks or longer until clinical and radiographic findings indicate healing.
- Infant is considered to be responsive to treatment only if:
 - ▶ Has been afebrile for 48-72 hrs
 - ▶ Local signs and symptoms of infection are reduced
 - ▶ WBC has normalized
 - ▶ CRP and/or ESR has decreased
- Adjunctive therapies to control pain and physical therapy.
- When the hip or shoulder joints are involved, prompt surgical decompression and drainage are crucial.

CHAPTER 25

Perinatal Asphyxia and Hypoxic Ischemic Encephalopathy

Essential characteristics of perinatal asphyxia are:

- Profound metabolic or mixed acidosis (pH <7.0) in umbilical cord arterial blood sample, if obtained.
- Persistence of an Apgar score of 0-3 for >5 min.
- Neurologic manifestations in the immediate neonatal period to include seizures, hypotonia, coma, or HIE.
- Evidence of multiorgan system dysfunction in the immediate neonatal period.

Etiology

Table (25-1): Factors Responsible for Perinatal Asphyxia

Maternal	<u>Inadequate oxygenation</u> <ul style="list-style-type: none"> • Hypoventilation during anesthesia • Cyanotic heart disease • Respiratory failure • Status epilepticus <u>Low maternal BP</u> <ul style="list-style-type: none"> • Acute blood loss • Severe anaphylactoid reaction • Compression of the vena cava & aorta by the gravid uterus
Utero-placental	Uterine tetany (excessive oxytocin) Uterine rupture Placental abruption Placental insufficiency (toxemia-postmaturity) Intrauterine growth restriction (IUGR) Umbilical cord prolapsed - compression - true knot

Table (25-1): Factors Responsible for Perinatal Asphyxia (Cont'd)

Fetal /Neonatal	<u>Failure of oxygenation</u> <ul style="list-style-type: none"> • Severe forms of cyanotic congenital heart disease • Severe pulmonary disease <u>Severe anemia</u> <ul style="list-style-type: none"> • Severe hemorrhage (twin-to-twin transfusion - fetomaternal hemorrhage) • Severe isoimmune hemolytic disease <u>Severe shock</u> <ul style="list-style-type: none"> • Overwhelming sepsis • Massive blood loss • Intracranial or adrenal hemorrhage • Cardiac arrhythmia
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Clinical Manifestations

A higher incidence is noted in term IDM's or toxemic mothers, infants with IURG, breech presentation, and postdates infants.

During labor

- Slow FHR, and loss of beat-to-beat variability
- Variable or late deceleration pattern
- Yellow, meconium-stained amniotic fluid

After birth

- Infants are depressed and fail to breathe spontaneously.
- Abnormal neurologic examination on the first day of life.
- According to Sarnat and Sarnat, HIE can be classified into 3 stages (**Table 25-2**).
- Infants can progress from mild to moderate and/or severe encephalopathy over the 72 hrs following the insult.

Table (25-2): Clinical Staging of Hypoxic Ischemic Encephalopathy in Term Infants

Signs	Stage 1 (Mild)	Stage 2 (Moderate)	Stage 3 (Severe)
Level of Consciousness	Hyperalert	Lethargic	Stuporous, coma
Muscle Tone	Normal	Hypotonic	Flaccid
Posture	Normal	Flexion	Decerebrate
Tendon Reflexes/Clonus	Hyperactive	Hyperactive	Absent
Myoclonus	Present	Present	Absent
Moro Reflex	Strong	Weak	Absent
Pupils	Mydriasis	Miosis	Unequal, poor light reflex
Seizures	None	Common	Decerebration
Electro-encephalographic	Normal	Low voltage changing to seizure activity	Burst suppression to isoelectric
Duration	<24hr	2-14 days	Hours to weeks
Outcome	Good (about 100% normal)	Variable 80% normal; abnormal if symptoms >5-7 days	Death (50%), remainder with severe deficits

N.B.: In infants on musculoskeletal blockade, seizures may be noted by abrupt changes in BP, HR, and oxygenation.

- Other multi-organ system dysfunctions
 - ▶ Kidney (acute tubular or cortical necrosis, hematuria)
 - ▶ Hematological (anemia, thrombocytopenia, DIC)
 - ▶ Cardiovascular (cardiomyopathy - hypotension/shock)
 - ▶ Pulmonary (PPHN, MAS, RDS, pulmonary hemorrhage)
 - ▶ Hepatic necrosis (cholestasis, hypoglycemia, coagulopathy, ↑ serum transaminases and ammonia)
 - ▶ Gastrointestinal (NEC, distension, bloody stools)

- ▶ Adrenal insufficiency (\downarrow glucose, \downarrow NA⁺, \uparrow K⁺ & hypotension)
- ▶ SIADH

Investigations

- CBC with differential
- Serum glucose level
- Arterial blood gas analysis
- Serum electrolyte, Ca⁺², phosphorus & magnesium levels
- Renal evaluation: BUN, creatinine, FE-Na, urine analysis (β 2 microglobulin) & renal ultrasound
- Cardiac evaluation: serum troponin & CK-MB.
- Hepatic evaluation: serum transaminases, albumin, bilirubin and ammonia levels, PT and APTT
- Neurologic evaluation: serum CK-BB
- Brain imaging [cranial sonar, CT scans (has limited ability to identify cortical injury within the first few days of life), MRI]
- EEG: to evaluate seizure activity and to define abnormal background activity.
- Brain stem function responses (prognostic significance).

Management of Perinatal Asphyxia

Prevention

- Proper antenatal care for pregnant mothers and identification of high risk pregnancies.
- Proper antenatal and intrapartum fetal assessment.
- Proper resuscitation measures.

Supportive measures

Adequate ventilation & oxygenation

- Maintain adequate ventilation: CO₂ should be maintained in the normal range; avoid hypercapnia & hypocapnia.
- Maintain adequate oxygenation (PaO₂ >40 mmHg in preterm infants & >50 mmHg in term infants); avoid hypoxia & hyperoxia.

Thermoregulation

- Maintain temperature in the normal range.
- Avoid hyperthermia.

Correction of metabolic acidosis

- Maintain acid-base status in the physiological ranges.
- Use volume expanders **cautiously**.
- Use sodium bicarbonate only when cardiopulmonary resuscitation is prolonged & the infant remains unresponsive.

Cardiovascular support

- Maintain arterial BP in the normal range for GA (**Refer to Appendix 6**); volume expanders & inotropic support may be required.
- Avoid systemic hypotension and hypertension with continuous monitoring of mean arterial BP.
- Avoid fluid overload.
- Give inotropic agents (e.g., dopamine or dobutamine) for cardiac dysfunction.

Maintenance of an optimum metabolic status

- Avoid hypoglycemia and hyperglycemia (maintain blood glucose level of 75-100 mg/dl).
- Maintain calcium within normal range.

Feeding

- Withhold feeding until good bowel sounds are heard and stools are negative for blood and/or reducing substances.

Renal support

- Monitor urine output & assess the infant's volume status.
- Oliguria is managed by maintenance of fluid balance (IWL + urine output) and daily measurements renal functions, serum electrolytes and assessment of the infant's weight.
- Consider low dose dopamine infusion (<5 µg/kg/min).

Liver support

- Monitor liver function.

Hematological support

- Monitor coagulation profile and correct abnormalities with FFP and/or platelet transfusion.

Control of brain edema

- In the first 2 days of life, restrict IV fluids to $\frac{2}{3}$ of the daily requirement.

Control of seizures (Refer to Chapter 26)

- Start with phenobarbital, and if seizures are not controlled by the maximum allowable dose, add phenytoin.
- Correct the metabolic cause if present.

Magnesium sulfate

- IV infusion (250 mg/kg/dose for 3 doses, 24 hrs apart) in term infants with severe perinatal asphyxia within 6 hrs of insult.
- Beware of hypotension, respiratory depression, and use with caution in infants with renal insufficiency.

CHAPTER 26

Neonatal Seizures

Seizures are paroxysmal alteration of neurologic function, including behavioral, motor, and/or autonomic changes.

Etiology

- Hypoxic ischemic encephalopathy: seizures usually occur within 12-24 hrs after the insult.
- Transient metabolic disturbances: hypoglycemia, hypocalcemia, hypomagnesemia, or hypo/hyponatremia
- Focal ischemic injury
 - ▶ Arterial infarction (neonatal arterial stroke); infants usually appear normal before and after seizures.
 - ▶ Venous infarction (2nd to systemic infection, polycythemia, or dehydration and in association with IVH in preterm infants); infants usually have a depressed mental status between seizures.
- Intracranial hemorrhage
- Infections: congenital infections, meningitis, or septicemia
- Less common causes
 - ▶ Inborn errors of metabolism
 - Pyridoxine (vitamin B6) dependency
 - Glycine encephalopathy (non-ketotic hyperglycinemia)
 - Maple syrup urine disease
 - Folinic acid responsive seizures
 - ▶ Brain anomalies: holoprosencephaly or lissencephaly
 - ▶ Epileptic syndromes

- Benign familial neonatal seizures: autosomal dominant, occur in the first 48-72 hrs of life and disappear by age 2-6 months.
- Benign idiopathic neonatal seizures (fifth-day fits): occur on day 5 of life (4-6 days) in normal-appearing neonates; multifocal seizures for <24 hrs.
- ▶ Maternal drug withdrawal
- ▶ Kernicterus

N.B.: An infant with convulsions may have more than one underlying cause.

Clinical Manifestations

Subtle seizures

- The most common subtype (~50%) of all seizures (more common in full-term infants).
- Usually occur in association with other types of seizures.
- Not associated with EEG seizures and have poor response to conventional anticonvulsants.
- Manifest in any of these ways:
 - ▶ Stereotypic movements of the extremities (bicycling or swimming movements).
 - ▶ Deviation or jerking of the eyes with repetitive blinking.
 - ▶ Drooling, sucking or chewing movements.
 - ▶ Apnea or sudden changes in the respiratory pattern, unlike apnea due to respiratory center depression, and associated with tachycardia rather than bradycardia.
 - ▶ Rhythmic fluctuations in vital signs.
- Despite the “subtle” expression of this seizure category, these infants may have suffered significant brain injury.

Tonic seizures

- Stiffening of parts of the body (either focal or generalized).
- Generalized tonic seizures

Chapter 26: Neonatal Seizures

- ▶ Mainly manifest in preterm infants with diffuse neurologic dysfunction or major IVH.
- ▶ Closely mimic decerebrate or decorticate posturing (tonic flexion or extension of the upper extremities, neck or trunk & tonic extension of the lower extremities).
- Focal tonic seizures
 - ▶ Present with asymmetric truncal posturing, tonic movements of a limb, or sustained head or eye turning.
 - ▶ Often associated with EEG seizures.

Clonic seizures

- Stereotypic and repetitive biphasic movements (a fast contraction phase and a slower relaxation phase); the rhythm is usually slow, 1-3 movements/ second.
- Clonic movements should be distinguished from the symmetric “to-and-fro” movements of jitteriness. Gentle flexion of the affected body part easily suppresses the tremor, whereas clonic seizures persist.
- They can involve any part of the body; most often involve one extremity or one side of the body.
- They may be unifocal, multifocal or generalized.

Myoclonic seizures

- Brief jerks of extremities or body that tend to involve distal muscle groups, lacking the slow return phase of the clonic movement complex.

Diagnosis

Maternal and obstetric history

- Maternal infections
- Drug exposure
- Previous abortions or infants with seizures (IEMs)
- Medical conditions (e.g., diabetes, hypertension...etc.)
- Family history of neonatal seizures

- Chorioamnionitis, fever, antepartum hemorrhage, difficult labor or fetal distress and low Apgar scores

Laboratory investigations

Primary tests

- Blood glucose
- Serum calcium and magnesium
- CBC with differential
- Serum electrolytes
- Arterial blood gas
- CSF analysis and culture
- Blood culture

Other tests

- Search for specific suspected causes (TORCH titers, ammonia level, amino acids in urine, etc).
- EEG (normal in 1/3 of cases), or video EEG monitoring.
- Cranial ultrasound, Brain CT scan or MRI.

Benign Movements Simulating Seizures

Jitteriness

- Differs from clonic seizures in these aspects:
 - ▶ Flexion and extension phases are equal in amplitude.
 - ▶ Infant is alert, with no abnormal gaze or eye movements.
 - ▶ Diminished by passive flexion or repositioning of the limb, and provoked by tactile stimulation (may be spontaneous).
 - ▶ No EEG abnormalities are present.
- Jitteriness is often seen in infants with hypoglycemia, drug withdrawal, hypocalcemia, hypothermia and in SGA infants. These spontaneously resolve within a few weeks.

Benign neonatal sleep myoclonus

- Occurs in healthy preterm and term infants during active sleep, and rapidly abolished by arousal.

- May be precipitated by gentle rhythmic rocking or tactile stimuli, and gentle restraint may increase them.
- Resolve spontaneously within a few months.

Sleep apnea

- Not associated with abnormal movements, but is usually associated with bradycardia.

Management of Seizures

- Achieve a patent airway, adequate breathing and circulation.
- Correct the underlying cause, if possible
 - ▶ Hypoglycemia: D10W IV (2 ml/kg) over 1 min, followed by a continuous infusion.
 - ▶ Hypocalcemia: calcium gluconate 2 ml/kg IV slow infusion, with observation of HR, repeat q6 hrs over the first 24 hrs.
 - ▶ Hypomagnesemia: MgSO₄ 50% (0.2 mg/kg) IM.
 - ▶ Sepsis: antibiotics after obtaining appropriate culture.
- Specific anticonvulsant agents: phenobarbital (the drug of choice), phenytoin (If not controlled with phenobarbital alone), and benzodiazepines (in status epilepticus)
- Refractory seizures: give pyridoxine 50-100 mg IV with EEG monitoring “therapeutic trial”; seizures will stop within minutes if pyridoxine dependency is the cause. In such cases, maintain on oral pyridoxine (10-100 mg/day).
- Give a trial of folinic acid for 24-48 hrs in infants failing to respond to anticonvulsants and pyridoxine (starting dose 2.5 mg twice/day, may be increased to 8 mg/kg/day).
- If, at the time of discharge, infant’s examination and EEG are normal, consider withdrawal of phenobarbital. Otherwise, the need for continued therapy should be re-evaluated at 6-12 wks intervals.

CHAPTER 27

Intracranial Hemorrhage

Subdural (SDH) Hemorrhage

Etiology

- Often related to birth trauma, and more common in full-term infants.

Clinical manifestations

- SDH should be suspected in cases with a history of trauma or a difficult delivery with the development of focal neurologic signs (e.g., unequal pupils, eye deviation, or hemiparesis).
- Symptoms may present over a period of a few hours to days, depending on severity and degree of hemorrhage.
- Non-specific signs (e.g., irritability, lethargy and poor Moro reflex).
- ↑Intracranial pressure (e.g., bulging anterior fontanelle and/or widely split sutures).
- Hypovolemia and anemia with massive hemorrhage.
- Posterior fossa hemorrhage may manifest with opisthotonus, apnea, bradycardia, altered mental state and seizures.

Investigations

- CT scan or MRI
- Ultrasound is inadequate for demonstrating SDH.

N.B.: If a large SDH is suspected, lumbar puncture (LP) is contraindicated until after CT scan.

Management

- Most infants do not require surgical intervention and are managed with supportive care.

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- If SDH is associated with displacement of the midline, refer the infant for a neurosurgical opinion for evacuation, especially if there is clinical deterioration with signs of transtentorial herniation.
- Massive posterior fossa SDH requires surgical evacuation.
- Monitor closely for detection of signs of deterioration.
- Monitor the head circumference at follow-up visits as hydrocephalus or chronic subdural effusion may occur.

Subarachnoid Hemorrhage (SAH)

Etiology

- Usually self-limiting and of venous origin.
- Trauma or hypoxic events may be important antecedents.

Clinical manifestations

- The majority of cases have minimal or no clinical signs.
- Less frequently, seizures may occur on the 2nd day of life, and the infant is usually well between seizures.
- Rarely, when associated with massive SAH, there is rapid neurologic deterioration. The infant usually has also sustained severe hypoxic-ischemic cerebral injury, with or without trauma, or has a major vascular abnormality, (e.g., arteriovenous malformation or aneurysm).

Investigations

- CSF: finding of uniformly blood-stained CSF with lumbar puncture
- CT scan or MRI

Management

- Usually symptomatic; anticonvulsant drugs for seizures.
- With very large SAH; blood transfusion and cardiovascular support should be provided and neurosurgical intervention may be required.

Intraparenchymal Hemorrhage (IPH)

Etiology

- Intracerebral hemorrhage, it may be:
 - ▶ Primary: rupture of an arteriovenous malformation or from a coagulation defect.
 - ▶ Secondary: more common (e.g., hemorrhage into a region of hypoxic-ischemic brain injury).
- Intracerebellar hemorrhage
 - ▶ It is more common in preterm infants.
 - ▶ It may primary or may result from extension of IVH.

Clinical manifestations

- ▶ Vary according to extent and site of hemorrhage.
- ▶ In term infants, it may manifest with focal neurological signs (seizures or hemiparesis).

Investigations

- CT scan or MRI, and cranial ultrasound

Management

- Small hemorrhages require supportive care.
- A large hemorrhage with severe neurologic compromise should prompt neurosurgical intervention.

Germinal Matrix Hemorrhage (GMH)/Intraventricular Hemorrhage (IVH)

Etiology

- IVH is found principally in preterm newborns. In term infants, it is usually associated with HIE and traumatic insult.
- Risk factors
 - ▶ Ischemia/reperfusion (e.g., rapid volume expansion after hypotension and hypertonic NaHCO_3 administration)
 - ▶ Fluctuation in cerebral blood flow (e.g., breathing out of synchrony with the mechanical ventilator, large PDA)

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- ▶ ↑Cerebral blood flow (e.g., hypertension, anemia, hypercarbia and seizures)
- ▶ ↑Cerebral venous pressure (e.g., pneumothorax, high CPAP or PEEP and aggressive tracheal suctioning)
- ▶ Platelet dysfunction and coagulopathy

Clinical manifestations

- Preterm infants
 - ▶ Usually silent (25-50%) and recognized only when a routine cranial ultrasound is performed.
 - ▶ Some infants present with gradual clinical deterioration with decreased levels of consciousness & spontaneous movements, hypotonia or abnormal extremity or eye movements, and altered neonatal reflexes.
 - ▶ Less often, the infant presents with catastrophic deterioration (sudden deterioration in the infant's clinical state, ↑O₂ or ventilatory requirement, ↓BP or acidosis, and severe neurologic signs (e.g., coma, severe hypotonia, decerebrate posturing and apnea). More often, however, a drop in Hct is seen without a clear change in the infant's condition.
- Term infants: typically present with signs as seizures, apnea, irritability or lethargy, vomiting or a full fontanelle. Catastrophic presentation is rare, unless there is another intracranial hemorrhage.

Complications

- Periventricular hemorrhagic infarction (PVHI)
- Post-hemorrhagic ventricular dilatation (PVD): it may occur after days or weeks; it may be asymptomatic or may present with increasing head growth, bulging fontanelle, disturbed conscious level, worsening respiratory status.

Investigations

- Cranial ultrasound: for screening and diagnosis (**Refer to chapter 10**)
- CT scan and MRI

Table (27-1): Grading of Intraventricular Hemorrhage

	Cranial Ultrasound	CT Scan
Grade I	GMH with no or minimal IVH (<10% of ventricular volume)	Isolated GMH
Grade II	IVH occupying 10-50 % of ventricular volume	IVH without ventricular dilatation
Grade III	IVH occupying >50% of ventricular volume with dilated ventricles	IVH with ventricular dilatation
Grade IV	<u>Separate notation</u> Periventricular echodensity (location and extent)	IVH with parenchymal hemorrhage

Prevention

- Antenatal glucocorticoids
- Slow infusion of colloids and hyperosmolar solutions
- Avoid hypotension and avoid fluctuations in arterial BP

Treatment

- Supportive care
 - ▶ Maintain normal BP and circulating volume.
 - ▶ Maintain normal acid base balance & electrolytes.
 - ▶ Transfuse with packed RBC's in large IVH.
 - ▶ Correct thrombocytopenia & coagulation disorders.
 - ▶ Treat seizures; if present.
- Management of PVD: serial cranial ultrasonography, serial lumbar punctures, surgical diversion of CSF flow, and rarely, drugs to ↓CSF production (acetazolamide and furosemide).

CHAPTER 28

Birth Injuries

Injury may occur antenatally, intrapartum, or during resuscitation.

Risk factors

Primiparity, cephalopelvic disproportion, dystocia, prolonged or unusually rapid labor, oligohydramnios, abnormal presentation of the fetus, VLBW or extreme prematurity, macrosomia, fetal anomalies, and forceps use or vacuum extraction

Head Injuries

Caput succedaneum

- Edema over the presenting part of the scalp during a vertex delivery.
- Clinical manifestations
 - ▶ A soft swelling, usually a few millimeters thick, and may be associated with overlying petechiae, purpura, or ecchymoses; its size is maximum just after birth
 - ▶ It has poorly defined margins and may extend across the midline of the skull and across suture lines.
 - ▶ Usually resolves spontaneously within several days, and treatment is often not required.

Cephalhematoma

- Subperiosteal collection of blood overlying a cranial bone.
- Clinical manifestations
 - ▶ The bleeding is sharply limited by periosteal attachments to the suture lines (i.e., no extension across suture lines).
 - ▶ Usually occurs over one or both parietal bones, less often it involves occipital bones and very rarely, frontal bones.

- ▶ The overlying scalp is not discolored.
- ▶ It may not be apparent for few hours after birth.
- ▶ It may feel fluctuant and a few days later, it is often bordered by a slightly elevated ridge of organizing tissue (false sensation of a central bony depression).
- ▶ It may be associated with skull fractures - usually linear.
- ▶ It usually resolves within 6-12 wks, occasionally with a residual calcification.
- Management
 - ▶ Not needed for treatment in uncomplicated cases.
 - ▶ Incision or aspiration is contraindicated (risk of infection).
 - ▶ Blood transfusion is required with marked blood loss.
 - ▶ Significant hyperbilirubinemia requires phototherapy or exchange transfusion depending on bilirubin level.
 - ▶ Associated linear fractures do not require specific therapy, but follow-up radiographs at 4-6 wks. Depressed fractures require immediate neurosurgical consultation.

Subgaleal hemorrhage (SGH)

- Collection of blood in the soft tissue space between the galea aponeurotica and the periosteum of the skull.
- Predisposing factors: difficult instrumental delivery (the most common), coagulopathies, prematurity, macrosomia, fetal dystocia and precipitous labor.
- It may result from an associated skull fracture.
- Clinical manifestations
 - ▶ Early manifestations are pallor, hypotonia and diffuse swelling of the scalp.
 - ▶ A fluctuating mass straddling cranial sutures, fontanelles, or both is highly suggestive of the diagnosis. It can spread across the entire calvarium.
 - ▶ Hematoma may grow slowly or increase rapidly → hypovolemic shock.

- ▶ Ecchymotic discoloration of the scalp, pitting edema and progressive posterior spread toward the neck and lateral spread around the ears (displacing ears anteriorly); periorbital swelling and ecchymosis are common.

N.B.: SGH should be considered in infants who show signs of hypoperfusion and falling Hct after attempted or successful vacuum delivery, even in the absence of a detectable fluctuant mass.

- Management
 - ▶ Observation for signs of hypovolemia and progression.
 - ▶ Prompt restoration of blood volume with FFP or blood.
 - ▶ Phototherapy provision, if hyperbilirubinemia develops.
 - ▶ Investigation for coagulopathies, in case there is no evidence trauma or instrumental delivery.
 - ▶ In the presence of continued deterioration, surgical drainage may be considered.

Injuries to the Neck and Shoulder

Fractured clavicle

- Most clavicular fractures are of the greenstick type, but occasionally the fracture is complete.
- Etiology: difficult delivery of the shoulders in vertex presentations and extended arms in breech deliveries.
- Clinical manifestations
 - ▶ Decreased movement of the ipsilateral arm
 - ▶ Pain on passive movement
 - ▶ Tenderness, crepitus over the clavicle
 - ▶ Absent Moro reflex on the involved side
 - ▶ About ⅓ of the cases present with a palpable mass (callus) at 7-14 days of life.
 - ▶ An x-ray confirms the diagnosis.
- Management
 - ▶ Immobilize the affected arm and shoulder for 7-10 days.

Brachial palsy

- Etiology: excessive traction of the head, neck, and arm during birth (e.g., shoulder dystocia & breech presentation)

A) Erb's paralysis (the most common form)

- Results from injury of C5, C6 (and occasionally C7) roots.
- Affected infant is frequently large and asphyxiated.
- The affected arm is held in adduction, internal rotation, with extension at the elbow & pronation of the forearm and flexion of the wrist. Moro, biceps, and radial reflexes are absent on the affected side. Grasp reflex is intact.
- Signs of respiratory distress indicate an accompanying ipsilateral phrenic nerve root injury.
- Management
 - ▶ Partial immobilization of the affected extremity for 1-2 wks in a position opposite to that held by the infant.
 - ▶ Gentle massage and passive exercises after 1-2 wks.
 - ▶ If no improvement, refer to a neurosurgeon.

B) Klumpke's paralysis

- Results from injury of C7, C8 & T1 roots.
- The hand is paralyzed, & voluntary movements of the wrist cannot be made. Grasp reflex is absent & deep tendon reflexes are intact.
- Dependent edema and cyanosis of the hand and trophic changes in the fingernails. After some time there may be flattening and atrophy of the intrinsic hand muscles.
- Usually ipsilateral Horner's syndrome (ptosis, miosis, and enophthalmos) is also present.

C) Total brachial plexus injury

- The entire arm is paralyzed; completely motionless, flaccid, and powerless, hanging limply to the side.
- All reflexes are absent and the sensory deficit may extend almost to the shoulder.

Phrenic nerve paralysis (C3-4-5)

- Results in diaphragmatic paralysis and rarely occurs as an isolated injury; mostly unilateral and associated with ipsilateral upper brachial plexus palsy.
- Difficult breech delivery is the most common cause.
- Clinical manifestations
 - ▶ Recurrent episodes of cyanosis, with irregular and labored respirations.
 - ▶ Breathing is almost completely thoracic (i.e., no bulging of the abdomen with inspiration on the affected side).
 - ▶ ↓ Breath sounds over the affected side.
 - ▶ Tachypnea, weak cry and apneic spells (in severe cases).
 - ▶ Chest x-ray reveals elevation of the corresponding cupola of the diaphragm.
 - ▶ Ultrasonography or fluoroscopy of the chest reveals elevated hemidiaphragm with paradoxical movement of the affected side with breathing.
- Management
 - ▶ Most infants require only nonspecific medical treatment.
 - ▶ Positioning of the infant on the involved side.
 - ▶ Oxygen administration for cyanosis or hypoxemia.
 - ▶ IV fluids may be necessary for the first few days. If the infant begins to show improvement, progressive oral or gavage feedings may be started.
 - ▶ Antibiotics are indicated if pneumonia occurs.
 - ▶ Infants with more severe respiratory distress (those with bilateral phrenic nerve palsy) may require MV.
 - ▶ If no improvement after 1 month, plication of diaphragm should be considered.

SCM injury (muscular or congenital torticollis)

- A well circumscribed, hard, immobile, fusiform mass, 1-2 cm in diameter, palpable in the mid-portion of SCM that may be present at birth (more often, noted at 1-4 wks of age).
- No inflammation or overlying discoloration.
- It enlarges during the following 2-4 wks, then gradually regresses and disappears within 3-4 months in the majority of cases.
- Transient torticollis after birth; the head tilts toward the involved side, and the chin is elevated and rotated (head cannot be moved passively into normal position).
- Management
 - ▶ As early as possible, the involved muscle should be stretched to an overcorrected position by gentle, even, and persistent motion with the infant supine. The head is flexed forward and away from the affected side, and the chin is rotated toward the affected side.
 - ▶ Instruct the mother to repeat this maneuver several times a day.
 - ▶ If the deformity has not been fully corrected (after 6 months), surgery should be considered.

Intra-abdominal Injuries**Clinical manifestations**

- History of a difficult delivery.
- Liver (subcapsular) hematoma
 - ▶ Generally asymptomatic at birth.
 - ▶ Signs of blood loss (as pallor, poor feeding, tachypnea, tachycardia) and jaundice developing during the 1st 1-3 days after birth; rupture → circulatory collapse.
- Splenic injury
 - ▶ A mass is sometimes palpable in the left upper quadrant
 - ▶ Abdominal radiograph shows displacement of stomach bubble medially.

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- Adrenal hemorrhage
 - ▶ Adrenal insufficiency (poor feeding, vomiting, diarrhea, dehydration, irritability, hypoglycemia and shock).

Investigations

- Abdominal ultrasound
- Adrenal function tests

Management

- Prompt transfusion with packed RBC's, and recognition and correction of any coagulation disorder.
- Laparotomy with evacuation of the hematoma and repair of any laceration.
- Adrenal insufficiency may require steroid therapy.

N.B: Intra-abdominal trauma should be suspected in any newborn with shock and abdominal distention or pallor, anemia, and irritability without evidence of external blood loss.

CHAPTER 29

Common GIT Problems

Gastroesophageal Reflux

Spontaneous and effortless regurgitation of the gastric contents into the esophagus

Clinical Manifestations

- Continual regurgitation and spitting up or non-bilious vomiting of small quantities of milk after feeding (forceful vomiting may be due to delayed gastric emptying)
- Signs of aspiration (pulmonary secretions, apnea/bradycardia, airway obstruction, and pulmonary deterioration)
- Signs of esophagitis (refusal to feed, irritability, arching of the back during feeding)
- Failure to thrive

Diagnosis

- In mild cases: careful clinical assessment, confirmed by assessment of response to therapy.
- In severe complex cases: upper GIT contrast series, 24 hrs pH monitoring

Treatment (based on the severity)**Non-pharmacological**

- Positioning
 - ▶ Prone position with head elevation (about 30°) during awake periods.
 - ▶ Place the infant in an upright position for 20-30 min after feeding; the use of infant seat is discouraged.

- Frequent feeding with small volumes; continuous gastric or transpyloric feeding can be given.
- Thickening formula or EBM with cereal (by adding 1 tablespoon of rice cereal per 2 oz of milk). For formula-fed infants, premixed "anti-reflux" formulas are available.

N.B.: The AAP recommends non-prone positioning during sleep to reduce the risk of sudden infant death syndrome (SIDS).

Pharmacological

- Promotion of gastric emptying and GI motility
 - ▶ Metoclopramide: 0.1-0.2 mg/kg/dose q6 hrs PO 30 min before feeds, or IV infusion over >30 min.
 - ▶ Erythromycin: 12 mg/kg/dose q6 hrs PO.
- Inhibition of gastric acid secretion and relieving esophagitis:
 - ▶ Omeprazole: 0.5-1.5 mg/kg/dose PO, once daily.
 - ▶ Ranitidine: PO (2 mg/kg/dose q8 hrs) or IV (0.5 mg/kg/dose q6 hrs over 30 min) or IV infusion (0.0625 mg/kg/hr).

Surgical

Fundoplication is performed for persistent, clinically compromising GER (recurrent aspiration pneumonia, failure to thrive, or apparent life-threatening apnea).

Gastric Aspirate (Residuals)

The process of stomach aspiration with oral or NG tube

Characteristics

Bilious aspirate (an obstructive lesion distal to ampulla of Vater)

- Bowel obstruction, NEC, meconium plug, meconium ileus, Hirschsprung's disease, malrotation, volvulus, ileus, or factitious (i.e., passage of tube into the duodenum)

Non bilious aspirate

- Problems with the feeding regimen

- ▶ Aspirate containing undigested formula (short feeding interval)
- ▶ Aspirate containing digested formula (delayed gastric emptying, overfeeding, or ↑formula osmolarity by added vitamins)
- Others: NEC, pyloric stenosis, post-NEC stricture, infections, IEMs, constipation, CAH/adrenal hypoplasia, or lactose intolerance

Bloody aspirate (Refer to GIT bleeding section in this chapter).

Clinical Manifestations

Depend on:

- Volume: excessive if >30% of the total formula given at the last feeding.
- Character: bilious, bloody, digested or undigested.
- Vital signs: abnormal signs indicate possible intra-abdominal pathologic process.
- Abdominal examination
 - ▶ Absence of bowel sounds may indicate ileus.
 - ▶ Absence of bowel sounds, distension, tenderness and erythema may indicate peritonitis.
- Frequency of stools: knowing when the last stool was passed.

Investigations

- Laboratory studies
 - ▶ CBC with differential to evaluate sepsis, Hct and platelet count if bleeding occurs.
 - ▶ Blood culture, if sepsis is suspected.
 - ▶ Serum potassium level, if ileus is present.
 - ▶ Stool pH, if there is family history of milk intolerance.
- Radiological studies
 - ▶ Upright plain x-ray of the abdomen (if bilious aspirate, abnormality on examination or aspirates continue): look for unusual gas pattern, pneumatosis intestinalis, ileus or bowel obstruction (multiple fluid levels).

- ▶ Abdominal ultrasonography and Doppler studies: in severe cases as pyloric stenosis, NEC & volvulus.
- Endoscopy: to be considered for ulcer evaluation.

Management

Bilious aspirate

- Surgical problem (bowel obstruction, malrotation or volvulus): place a NG tube with continuous NG suction and request pediatric surgeon consultation.
- Ileus: keep NPO, place a NG tube and treat the cause.
- Factitious: confirm the NG tube by an x-ray film (distally in the duodenum); replace or reposition in the stomach.

Non-bilious aspirate

- Aspirate containing undigested formula
 - ▶ Use breast milk wherever available.
 - ▶ If <30% of the previous feed & the physical examination and vital signs are normal, replace the aspirate.
 - ▶ Increase feeding interval to 3 hrs instead of 2 hrs.
 - ▶ If aspirate continues, re-evaluate, obtain an abdominal x-ray film, and try continuous gavage feedings (oral feedings may be discontinued for a time to rest the gut).
- Aspirate containing digested formula
 - ▶ Discard the aspirate (especially if containing a large amount of mucus).
 - ▶ If vital signs and physical examination are normal, continue feeding and stomach aspiration.
 - ▶ Be sure that overfeeding is not occurring.
 - ▶ If aspirate continues, re-evaluate the infant, obtain an abdominal x-ray film and temporarily discontinue oral feedings to rest the gut.
- Treat the underlying cause.

Bloody aspirate (Refer to GIT bleeding section in this chapter)

Bleeding from Upper GI Tract

Vomiting bright red blood or active bleeding seen from NG tube

Etiology

Idiopathic (>50%), swallowing of maternal blood (10%), liver diseases, oropharyngeal trauma, stress ulcer, NG trauma, NEC, coagulopathy, drugs (indomethacin, or corticosteroids), pyloric stenosis or severe fetal asphyxia

Clinical Manifestations

Vary from a clinically stable newborn with normal vital signs to a newborn with severe signs of shock, infection and asphyxia.

- Swallowing of maternal blood (during CS): occurs during the first day of life in a clinically stable infant.
- Coagulopathy: bleeding from other sites.
- Volvulus or NEC: abdominal distension, erythema, and/or abdominal wall edema.
- Liver disease: jaundice, easy bruising, change in color of stools may signal.
- Oropharyngeal trauma: detected on examination of the nose and oral cavity.

Investigations

- Laboratory studies
 - ▶ Apt test: if swallowed maternal blood is suspected (place the blood in a test tube, add sterile water, and then mix with NaOH 1%, if the solution turns to yellow brown (indicating maternal blood), while if it remains red (indicating newborn's blood).
 - ▶ Check Hct level, as soon as, possible for a base line value and serially to assess the need for transfusion (Hct may not reflect blood loss for several hours in acute bleeding).
 - ▶ Check platelet count.
 - ▶ Conduct coagulation studies (PT, APTT & fibrinogen) to rule out DIC and other coagulopathies.

- Radiologic studies
 - ▶ Abdominal x-ray film to rule out NEC.
 - ▶ Abdominal ultrasound if pyloric stenosis is suspected.
- Endoscopy: to be considered for ulcer evaluation.

Management

General measures

- Obtain an IV access with 2 large bore IV catheters (23 gauge), if acute bleeding is suspected and the infant is not hemodynamically stable
- Gastric lavage with $\frac{1}{2}$ NS or NS (avoid cold solutions)
- Epinephrine lavage (1:10,000 solution), 0.1 ml diluted in 10 ml of sterile water, if tepid water lavage failed
- Crystalloid replacement (usually NS), if BP is dropping
- Blood replacement (depending on Hct)

Specific measures

- Idiopathic cases: no other treatment
- Swallowing of maternal blood: no specific treatment
- Stress ulcer: ranitidine
- NG trauma: use the smallest NG tube possible with gentle insertion
- Coagulopathy
 - ▶ HDN: vitamin K₁ IV or SC; consider FFP administration.
 - ▶ DIC: treat the underlying cause; support BP with multiple transfusions of colloid and platelets, if needed
 - ▶ Congenital coagulopathies: hematologist consultation.
 - ▶ Drug induced bleeding: stop the causative drug
- Gastric volvulus & duplication: urgent surgical consultation
- Pyloric stenosis: hydration and surgical consultation

Necrotizing Enterocolitis (NEC)

NEC incidence is inversely proportional to birth weight (70-90% of cases are preterm infants “predominantly VLBW”).

Risk Factors

- Prematurity; the mean GA of NEC is 30-32 wks.
- Asphyxia and acute cardiopulmonary diseases (e.g., PDA)
- Enteral feeding
 - ▶ Preterm formula-fed infants
 - ▶ Rapid advancement in enteral feedings
- Polycythemia and hyperviscosity syndromes
- Exchange transfusion
- Enteric pathogenic microorganisms (e.g., *E.coli*, *Klebsiella*)
- Others: umbilical artery catheterization

Clinical Manifestations

- Age of onset is inversely proportional to birth weight and GA (in VLBW infants, the onset is usually between 14-20 days; however, in full-term infants, the onset is usually within the first week).
- Clinical features are divided into systemic and abdominal signs; most infants have a combination of findings.
 - ▶ Systemic signs:
Respiratory distress, apnea &/or bradycardia, lethargy, temperature instability, irritability, poor feeding, hypotension, poor peripheral perfusion, shock, acidosis, oliguria and DIC
 - ▶ Abdominal (enteric) signs:
Feeding residual, abdominal distention, tenderness, vomiting (bilious and/or bloody), ileus, abdominal wall erythema or induration, persistent localized abdominal mass, ascites & occult/gross blood in stool

N.B.: Early diagnosis by careful clinical observation for nonspecific signs in infants who are at risk to develop NEC is the most important factor in determining outcome.

Staging Criteria of NEC

Table (29-1): Modified Bell Staging Criteria

Stage	Systemic Signs	Intestinal Signs	Radiological Signs
IA Suspected NEC	Nonspecific (apnea, bradycardia, lethargy & temperature instability)	Elevated pre-gavage residuals, mild abdominal distension, Emesis, & Heme-positive stools	Normal or nonspecific (intestinal dilatation, mild ileus)
IB Suspected NEC	Same as stage IA	Bright red blood from rectum	Same as stage IA
IIA Definite NEC (mildly ill)	Same as stage IA	Same as stage IA + absent bowel sounds, +/- abdominal tenderness	Intestinal dilatation, Ileus, and Pneumatosis intestinalis
IIB Definite NEC (moderately ill)	Same as stage IIA + Mild acidosis, and thrombocytopenia	Same as stage IIA + absent bowel sounds, + definite abdominal tenderness +/- abdominal cellulitis or right lower quadrant mass	Same as stage IIA + Portal venous gas +/- Ascites
IIIA Advanced NEC (severely ill, bowel intact)	Same as stage IIB + Respiratory & metabolic acidosis, severe apnea, hypotension, decreased urine output, neutropenia and DIC	Same as stage IIB + Signs of generalized peritonitis, marked tenderness, distention of the abdomen, discoloration & induration of abdominal wall	Same as stage IIB + Definite ascites
IIIB Advanced NEC (severely ill, bowel perforated)	Same as stage IIIA	Same as stage IIIA	Same as stage IIIA + Pneumoperitoneum

Investigations

- Laboratory studies
 - ▶ CBC with differential: may be leukocytosis with shift to the left and thrombocytopenia.
 - ▶ Blood culture: for aerobes or anaerobes and fungi.
 - ▶ Stool analysis: for blood and carbohydrate (stool Clinitest)
 - ▶ Arterial blood gases: metabolic or combined acidosis.
 - ▶ Serum BUN, creatinine and electrolytes.
 - ▶ Serial CRP

N.B.: Thrombocytopenia, persistent metabolic acidosis and severe refractory hyponatremia are the most common triad of signs of advanced cases.

- Radiologic studies
 - ▶ Abdominal x-ray studies (anteroposterior and left lateral decubitus views) every 6-8 hrs during the 1st 2-3 days.
 - ▶ Films may reveal: bowel wall edema and a fixed-position loop on serial studies, pneumatosis intestinalis (the radiologic hallmark), portal or hepatic venous air, pneumoperitoneum (football sign or air under the diaphragm)

Management

Basic NEC protocol

It should be started promptly when signs suggestive of NEC are present, based on the severity of the condition.

General rules

- Stop enteral feedings immediately; start IV fluids and TPN to maintain basal nutritional needs (90-110 kcal/kg/day).
- Gastric drainage: place an appropriate-sized NG tube for either free drainage or intermittent suction.
- Monitor closely: vital signs, abdominal circumference, fluid intake and output (maintain urine output 1-3 ml/kg/hr) & GIT bleeding

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- Obtain bacterial cultures for aerobes and anaerobes from the stool, blood, NG aspirate, and CSF (if suspicion of meningitis).
- Antibiotics
 - ▶ Initiate IV ampicillin and gentamicin (or cefotaxime) therapy; add metronidazole for anaerobic coverage. Therapy can be adjusted based on culture results.
 - ▶ Maintain therapy for 7-14 days depending on the severity. If no organism is found and the diagnosis is questionable, antibiotics may be stopped after 3 days.
 - ▶ If staph epidermidis is suspected, a combination of vancomycin and gentamicin may be chosen.

Evaluate frequently (every 6-8 hrs initially)

- Physical examination including abdominal girth
- Abdominal x-ray studies
- Serum electrolytes, arterial blood gases, and CBC

Consider other interventions

- Clotting studies, if bleeding develops.
- Supplemental O₂ and MV, as required.
- Cardiovascular support with volume expansion (10 ml/kg - NS or FFP); repeated boluses may be needed.
- Low dose dopamine (3-5 µg/kg/min).
- Removal of umbilical catheter and placement of peripheral line.
- Paracentesis, if deterioration or abdominal erythema develops.
- Metabolic acidosis: volume expansion and NaHCO₃, as required.
- Platelet transfusions for severe thrombocytopenia, packed RBCs transfusion to maintain Hct >35%, and FFP administration to treat DIC.

Surgical treatment

Indications

- Pneumoperitoneum, positive paracentesis, erythema on the abdominal wall, abdominal mass, or portal venous gas

- Nonspecific supportive findings: abdominal tenderness, persistent thrombocytopenia, progressive neutropenia, clinical deterioration, or severe GI bleeding

Guidelines for refeeding

- Feedings may be started when antibiotic therapy is completed - abdominal x-ray is normal - clinical signs and symptoms of NEC are absent.
- Generally, NG decompression is stopped after 2 wks of treatment; feedings can be started very slowly with TPN gradually tapered off. Breast milk is preferred.
- Volume and strength should not be increased simultaneously; advance feeds over 10-14 days.

CHAPTER 30

Neonatal Hematological Problems

Bleeding

Etiology

Clotting factors deficiencies

- Transient deficiency of vitamin K dependent factors (II, VII, IX, X)
- DIC, shock, NEC, and renal vein thrombosis
- Inherited abnormalities of clotting factors: hemophilia or Von Willebrand disease (VWD)

Platelet disorders

- Maternal drug use (phenytoin, phenobarbital, or salicylates)
- Thrombasthenia: Glanzmann & Bernard-Soulier syndromes
- Thrombocytopenia (**Table 30-1**)

Vascular causes (e.g., arteriovenous malformations or hemangiomas)

Miscellaneous problems (e.g., liver dysfunction)

Table (30-1): Causes of Neonatal Thrombocytopenia

Maternal Disorders	Neonatal Disorders
<i>Drug use</i> <ul style="list-style-type: none"> • Heparin • Quinine • Hydralazine, • Tolbutamide • Thiazide diuretics 	<i>↓Platelet production</i> <ul style="list-style-type: none"> • Wiskott-Aldrich syndrome • Amegakaryotic thrombocytopenia • TAR syndrome • Fanconi anemia • Leukemia, neuroblastoma • Infections or drug induced, congenital CMV & rubella

Table (30-1): Causes of Neonatal Thrombocytopenia (Cont'd)

Infections <ul style="list-style-type: none"> • TORCH infections • bacterial infections • viral infections 	↑ Platelet destruction <ul style="list-style-type: none"> • ↑ Consumption in sick infants • Bacterial or viral infections, TORCH, DIC, cold injury, birth asphyxia & NEC • Kasabach-Merritt syndrome • Neonatal thrombosis
HELLP syndrome	After exchange transfusion by old blood (>24 hrs old)
Immune thrombocytopenia <ul style="list-style-type: none"> • Alloimmune (isoimmune) • Autoimmune (ITP, SLE) • Hemolytic disease of the newborn 	Polycythemia, hyperviscosity

HELLP syndrome: hemolytic anemia, elevated liver enzymes & low platelet count, ITP: immune thrombocytopenic purpura, SLE: systemic lupus erythematosus

Hemorrhagic Disease of the Newborn (HDN)

Clinical manifestations

Early disease (1st day of life)

- Occurs in infants born to mothers taking oral anticoagulants or anticonvulsants (e.g., phenytoin, or phenobarbital).
- Infant often have serious bleeding (intracranial hemorrhage).
- Mother should receive vitamin K₁ 10 mg IM 24 hrs before delivery.

Classic disease (day 2-7 of life)

- Occurs when the infant is not given vitamin K₁ prophylaxis at birth.
- Infant may have cutaneous, GI, or circumcision bleeding. Bruising may be seen around the nose or the umbilical cord.

Late onset disease (between 2nd week and 6th month)

- Associated with biliary atresia, hepatitis, cystic fibrosis, chronic diarrhea, and antibiotic therapy.
- Infants may have cutaneous, GI or intracranial hemorrhages.

Laboratory findings

- Normal platelet count & prolonged PT & APTT

Management

- Prophylaxis
 - ▶ Vitamin K₁ 0.5-1 mg IM given at the time of delivery.
 - ▶ Infants receiving TPN or antibiotics for >2 wks should be given 0.5-1 mg vitamin K₁ IM or IV weekly.
- Treatment
 - ▶ Vitamin K₁ (1-2 mg slow IV one dose); avoid IM injection (risk of bleeding)
 - ▶ FFP administration (10 ml/kg IV)
 - ▶ Fresh blood transfusion for serious bleeding

Disseminated Intravascular Coagulation (DIC)

Risk factors

Infection (e.g., gram -ve sepsis, systemic candidiasis and HSV), acidosis, hypoxia, hypotension, RDS, or massive hemolysis

Clinical manifestations

The baby usually appears sick; he shows petechiae, GI bleeding, oozing from venipunctures and bleeding from body orifices.

Laboratory findings

- ↓Platelet count, prolonged PT and APTT.
- Fragmented RBCs in blood smear, ↓fibrinogen, and ↑FDP's & D-dimer

Management

- Treat the underlying cause.
- Vitamin K₁ (1 mg slowly IV).
- Platelets transfusion to keep platelets >50,000/ μ L.
- FFP administration
- If bleeding persists, one of the following is done:
 - ▶ Exchange transfusion with fresh citrated whole blood
 - ▶ Platelets, packed RBCs, or FFP transfusions, as needed

- ▶ Cryoprecipitate (10 ml/kg)
- ▶ If DIC is associated with thrombosis and not with bleeding, give heparin IV infusion (10-15 units/kg/hr)

Neonatal Thrombocytopenia

Definition

Platelet count $<150,000/\mu\text{L}$ in a full term infant and $<100,000/\mu\text{L}$ in a preterm infant

Clinical manifestations

- Generalized superficial petechiae and bruising.
- Mucosal & spontaneous hemorrhage (if $<20,000/\mu\text{L}$).
- Intracranial hemorrhage may occur in severe cases.

Diagnosis

Table (30-2): Diagnostic Approach to Neonatal Thrombocytopenia

Sick Infant		Healthy Infant	
Normal PT, APTT	↑PT, APTT	Normal Mother's Platelet Count	↓Mother's Platelets
<ul style="list-style-type: none"> • Infection (without DIC) • Hypersplenism • Bone marrow infiltration • NEC 	<ul style="list-style-type: none"> • DIC • Sepsis • Hypoxia • Acidosis • Cold stress • Severe liver disease 	<ul style="list-style-type: none"> • Alloimmune thrombocytopenia • Neonatal drugs • Hemangioma • Congenital thrombocytopenia • Maternal ITP in remission 	<ul style="list-style-type: none"> • Maternal ITP • Maternal drugs • Familial

DIC: disseminated intravascular coagulopathy, NEC: necrotizing enterocolitis, ITP: immune thrombocytopenic purpura

Management

- Treat the underlying cause.
- Platelet transfusion (1 unit/3 kg) through a peripheral vein, when there is bleeding or platelet count $<20,000/\mu\text{L}$.

Alloimmune thrombocytopenia

- Platelet transfusion: if the infant has bleeding or has a platelet count $<20,000/\mu\text{L}$, use mother's platelets (collected 24 hrs before delivery). If not previously collected, mother's whole blood or platelets from HPA-1a- negative platelet donor can be used.
- IVIG (1 gm/kg/day for 2 days or 0.5 gm/kg/ day for 4 days).
- Prednisone (2 mg/kg/day), with continued low platelet counts.
- Cranial ultrasonography after delivery.

Diagnostic Work-up of a Bleeding Newborn**Table (30-3): Laboratory Evaluation of Bleeding in a Newborn**

Condition	Platelet Count	PT	APTT
Well Neonate			
• Vitamin K deficiency	Normal	↑	↑
• Thrombocytopenia	↓	Normal	Normal
• Hemophilia	Normal	Normal	↑
• Localized cause	Normal	Normal	Normal
Sick Neonate			
• DIC	↓	↑	↑
• Liver disease	Normal - ↓	↑	↑
• Infection	Normal - ↓	Normal	Normal - ↑

- Apt test: to rule out swallowing of maternal blood
- PT (for extrinsic pathway), APTT (for intrinsic pathway): both tests (for the common pathway “factors V, II and fibrinogen”)
- Peripheral blood smear (platelets and fragmented RBCs)
- Fibrinogen assay may be decreased in liver disease & in DIC
- D-dimer assay in infants with DIC and liver diseases
- Specific factor assays & Von-Willebrand panels
- Platelet function tests in suspected cases
- Bleeding times is less reliable to use

Neonatal Anemia

Defined as a central venous Hb level <13 gm/dl or a capillary Hb level of <14.5 gm/dl in infants of >34 wks' GA. It is usually defined by Hb or Hct value that is >2 SD below the mean for age.

Etiology

Hemorrhagic anemia

If blood loss is recent, Hct & reticulocyte count may be normal with normal bilirubin level, while the infant may be in shock; Hct will decrease later.

Table (30-4): Causes of Neonatal Hemorrhagic Anemia

Obstetric Causes	Bleeding in the Neonatal Period
<ul style="list-style-type: none"> • Abruptio placenta -placenta previa • Incision of placenta during cesarean section • Rupture of the cord • Fetomaternal transfusion or transplacental hemorrhage • Twin-twin transfusion syndrome 	<i>Non-exteriorized bleeding</i> <ul style="list-style-type: none"> • Intracranial bleeding • Massive cephalhematoma • Subcapsular hematoma, ruptured liver or spleen, adrenal hemorrhage
	<i>Exteriorized bleeding</i> <ul style="list-style-type: none"> • Bleeding from the umbilicus (tearing or cutting of the umbilical cord) • NEC or trauma by NG catheter
	<i>Repeated blood sample</i>

Table (30-5): Twin to Twin Transfusion

Donor Twin	Recipient Twin
Small for gestational age (SGA) >20% smaller than recipient twin	Large for gestational age (LGA) >20% larger than donor twin
Pale – anemic	Plethoric - polycythemic
Poor peripheral perfusion	Jaundice

Hemolytic anemia

↓Hct, ↑reticulocyte count, and ↑bilirubin level

- Immune: Rh, ABO, minor blood group incompatibilities, maternal disease (e.g., SLE, autoimmune hemolytic anemia)

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- Hereditary: spherocytosis, G6PD deficiency & α -thalassemia
- Acquired: infection, DIC, vitamin E deficiency & vitamin K overdose

Hypoplastic anemia (\downarrow RBC's production)

\downarrow Hct, \downarrow reticulocyte count, and normal bilirubin level

- Diamond-Blackfan anemia
- Fanconi anemia
- Congenital leukemia
- Infection (e.g., rubella and parvovirus)
- Suppression by maternal drugs such as chloramphenicol
- Physiologic anemia or anemia of prematurity

Clinical Manifestations

- Pallor may be the only obvious sign.
- Respiratory distress or irritability in chronic blood loss.
- Physical findings
 - ▶ Short stature and/or dysmorphic features: Fanconi anemia and Diamond-Blackfan anemia
 - ▶ Blueberry muffin spot and microcephaly: congenital infections
 - ▶ Jaundice: hemolytic anemia
 - ▶ Petechiae: bone marrow infiltration/failure, DIC, and sepsis
 - ▶ Congestive heart failure: chronic anemia
 - ▶ Giant hemangioma: Kasabach-Merritt syndrome
- With acute blood loss, symptoms of shock (\downarrow BP, cyanosis and poor perfusion).

Investigations

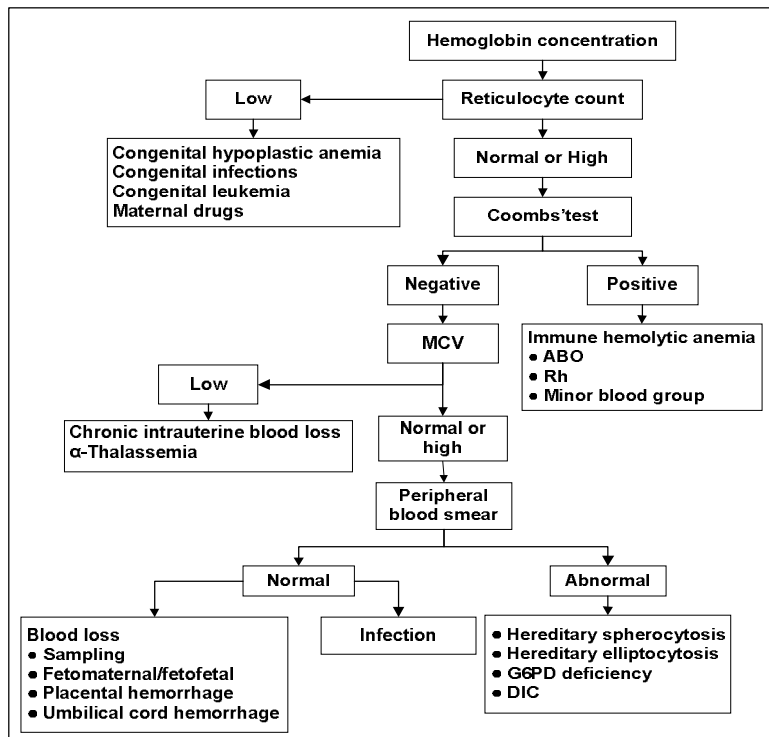
- CBC (Hb, Hct, and RBC's indices)
- Reticulocyte count

Corrected reticulocyte count =

Observed reticulocyte count \times Observed Hct

Normal Hct for age

- Other tests (may be required)
 - ▶ Blood smear, direct Coomb's test, bilirubin (total and direct), blood group and Rh type, hemolytic profile (Hb electrophoresis, osmotic fragility tests)
 - ▶ Kleihauer-Betke test (fetomaternal hemorrhage)
 - ▶ TORCH screening
 - ▶ Ultrasound of the head and abdomen
 - ▶ Bone marrow examination



MCV: Mean corpuscular volume, DIC: disseminated intravascular coagulopathy

Figure (30-1): Diagnostic approach to anemia in a newborn infant

Management

Frequent Hb, Hct, and bilirubin levels should be drawn

Transfusion

Indications

- Acute blood loss
- Hct <40% with significant respiratory disease or CHD; fresh blood should be used
- Premature infants, if:
 - ▶ Hct <21%: asymptomatic infants but with low reticulocyte count (<2%)
 - ▶ Hct <31% and
 - Hood oxygen <36%, or
 - MAP <6 cmH₂O by CPAP or IMV, or
 - >9 apneic and bradycardic episodes per 12 hrs or 2/24 hrs requiring bag and mask ventilation while on adequate methylxanthine therapy, or
 - HR >180/min or RR >80/min sustained for 24 hrs, or
 - Weight gain of <10 gm/day for 4 days on 100 kcal/kg/day, or
 - Having surgery
 - ▶ Hct <36% and requiring >35% O₂ or MAP 6-8 cmH₂O by CPAP or IMV.
- Infant with ABO incompatibility with excessive hemolysis and who do not have an exchange transfusion

Blood products

- Packed RBCs: calculate the volume of transfusion as follows:

Volume required (ml) =

$\frac{\text{Weight (kg)} \times \text{Blood volume/kg} \times (\text{Hct Desired} - \text{Hct Observed})}{\text{Hct of blood to be given}}$

- ▶ Average blood volume in a newborn = 80 ml/kg

- ▶ Hct of packed RBCs = 60-80% (check before transfusion).
- ▶ Generally, transfuse 10-15 ml/kg; unless rapid replacement is required for acute blood loss or shock, infuse no faster than 2–3 ml/kg/hr
- Whole blood (15-20 ml/kg) in acute blood loss
- Isovolemic exchange transfusion using high Hct packed RBC's may be required for severely anemic infants.

N.B.: Limiting donor exposures is recommended by assigning the aliquots from a single unit to a single patient.

Prophylaxis

Nutritional supplementation

- Term infants should be sent home on iron fortified formula if they aren't breastfeeding.
- Preterm infants: iron supplementation 2-4 mg/kg/day once full enteral feed is achieved. It is not advised in preterm neonates before 34 wks' gestation.
- Vitamin E 25 IU until the baby is 40 wks postconception or is discharged.
- Folic acid (1-2 mg/wk for preterm infants & 50 µg/day for term infants)

Recombinant human erythropoietin (rh-EPO)

- Can be initiated when infants are stable and can tolerate iron supplementation.
- Supplemental oral iron needs to be provided at 2 mg/kg/day as soon as tolerated (increase the dose to 6 mg/kg/day as soon as the infant is tolerating full enteral feeds).

Table (30-6): Guidelines for the Use of Erythropoietin

- Eligibility criteria
 - ▶ Birth weight $\leq 1,250$ gm and < 31 wks' GA with all of the following:
 - Total caloric intake ≥ 50 kcal/kg/day with $> 50\%$ enteral
 - Hct $< 40\%$ or $40\%-50\%$ but falling 2% per day
 - Mean airway pressure (MAP) < 11 cm H₂O and $FiO_2 < 0.4$
 - Postnatal age > 6 days and GA < 33 wks
 - ▶ Any infant with birth weight $1,251-1,500$ gm and phlebotomy losses > 5 ml/kg/week who meet the previous criteria
- Exclusion criteria: major anomalies, dysmorphic syndromes, hemolytic anemia, and active major infection
- Dosage: 250 units/kg/dose, SC, 3 times weekly
- Duration: till infant reaches 34 wks' postconceptional age
- Monitoring of therapy:
 - ▶ Blood pressure (risk of hypertension),
 - ▶ Platelet count (risk of thrombocytosis),
 - ▶ Hct and reticulocyte count: a base line measurement should be obtained at the time of therapy and followed weekly. Adjust the dose to maintain reticulocyte count $> 6\%$
- Discontinue if Hct reaches 45% without transfusion.

Polycythemia

Defined as a venous hematocrit $\geq 65\%$

Etiology (Table 30-7)

Clinical Manifestations

- Infants are either asymptomatic or symptomatic
- Delayed capillary refill and plethora
- Lethargy, irritability, hypotonia, seizures & cerebral infarction
- Cyanosis, apnea, tachypnea, murmurs, CHF & cardiomegaly
- Poor feeding, NEC with early feeding
- Hematuria, proteinuria & renal vein thrombosis
- Thrombocytopenia, DIC & jaundice

- Hypoglycemia & hypocalcemia

Table (30-7): Causes of Polycythemia in Neonates

Placental RBCs Transfusion	Placental Insufficiency - Intrauterine Hypoxia	Other Conditions
<ul style="list-style-type: none"> • Delayed cord clamping or forceful uterine contraction before clamping • Cord stripping • Holding the neonate below the mother at delivery • Maternal-fetal transfusion • Twin-twin transfusion 	<ul style="list-style-type: none"> • SGA • Maternal smoking • Maternal hypertensive disorders • Postmaturity • Maternal heart disease • Pregnancy at high altitudes 	<ul style="list-style-type: none"> • IDM • LGA • Beckwith Wiedemann syndrome • Dehydration • Trisomy 21 • Maternal use of propranolol • Congenital thyrotoxicosis • Congenital adrenal hyperplasia

SGA: small for gestational age, LGA: large for gestational age, IDM: infant of a diabetic mother

Laboratory Studies

Hct level, serum glucose, bilirubin and calcium levels and platelet count

Treatment

- Asymptomatic infant and Hct 65-70%: increase fluid intake and repeat Hct in 4-6 hrs.
- Asymptomatic infant with a venous Hct >70%: perform partial exchange transfusion (controversial)
- Symptomatic infant with a venous Hct >65%: perform partial exchange transfusion to bring the Hct level to 50-60%; withdraw blood from the umbilical vein and replace it with saline (preferred) or albumin 5 % in a peripheral vein.

Volume of exchange in ml =

$$\frac{(\text{Observed Hct} - \text{Desired Hct}) \times (\text{Body weight [kg]} \times \text{Blood volume/kg})}{\text{Observed Hct}}$$

CHAPTER 31

Neonatal Cardiac Disorders

When to Suspect Cardiac Disorders in a Neonate?

Abnormal physical findings

- Cyanosis, particularly when it doesn't improve with O₂.
- Pulse
 - ▶ Decreased or absent peripheral pulses in the lower extremities suggest coarctation of aorta.
 - ▶ Generally weak peripheral pulses suggest hypoplastic left heart syndrome or shock.
 - ▶ Bounding peripheral pulses suggest PDA.
- Heart murmur
- Irregular rhythm and abnormal HR suggest arrhythmia
- Hepatomegaly, may suggest heart failure.

Abnormal chest x-ray films

- Cardiomegaly
- Abnormal cardiac silhouette: boot-shaped heart in tetralogy of Fallot, egg-shaped heart in TGA, or dextrocardia
- Pulmonary vascular markings
 - ▶ ↑Pulmonary vascularity
 - Cyanotic: TGA, truncus arteriosus, or single ventricle
 - Acyanotic: VSD, or PDA
 - ▶ ↓Pulmonary vascularity: pulmonary atresia, tricuspid atresia, or tetralogy of Fallot

Manifestations of Cardiac Disorders in Neonates

1- Heart murmurs

Innocent murmurs

- >50% of full-term infants have innocent systolic murmurs during the first week of life.
- Pulmonary flow murmur (the most common)
 - ▶ Grade 1-2/6 systolic ejection murmur
 - ▶ Radiates well to the sides and the back of the chest.
- Others: transient systolic murmur of PDA, transient systolic murmur of tricuspid regurgitation and vibratory systolic murmur.

Pathologic murmurs

- Stenotic lesions (e.g., aortic stenosis, pulmonary stenosis, aortic coarctation): systolic ejection murmur noted shortly after birth.
- Left-to-right shunt lesions (e.g., VSD): pansystolic murmur may not be heard until the 2nd to 3rd week of life.
- Continuous murmur of PDA may appear early in preterm infants.

2- Cyanosis

- Tip of the tongue is a good place to look for central cyanosis.
- Cyanosis is usually recognized when $\text{SaO}_2 < 85\%$; however, it may occur at SaO_2 as high as 90% in this age group.
- Hyperoxia test
 - ▶ Distinguishes cyanotic CHD from pulmonary disease.
 - ▶ PaO_2 should be measured in room air (if tolerated), followed by repeat measurements with the infant receiving 100% O_2 through an oxyhood (at least 10 min).
 - $\text{PaO}_2 > 250$ mmHg in both upper and lower extremities eliminates critical structural CHD.
 - $\text{PaO}_2 < 100$ mmHg is diagnostic of cyanotic CHD (failed hyperoxia test).
 - PaO_2 between 100-250 mmHg may note structural heart disease with intracardiac mixing and markedly increased

pulmonary blood flow or severe pulmonary disease (equivocal results).

- Infants who fail a “hyperoxia test” or have equivocal results with other cardiac signs are likely to have congenital lesions:
 - a) Duct-dependent systemic blood flow (left sided obstructive lesions): critical aortic stenosis, coarctation of aorta, interrupted aortic arch, or hypoplastic left heart syndrome.
 - b) Duct-dependent pulmonary blood flow (right-sided obstructive lesions): critical pulmonary stenosis or pulmonary atresia, tricuspid atresia, tetralogy of Fallot (with severe right ventricular outflow tract obstruction), or Ebstein anomaly.
 - c) Lesions with complete intracardiac mixing: truncus arteriosus, or total anomalous pulmonary venous return.
 - d) Lesions with parallel circulation: TGA

Table (31-1): Central Cyanosis in a Neonate

Disorders	Causes	Features
CNS Depression	<ul style="list-style-type: none"> • Perinatal asphyxia • Heavy maternal sedation • Intrauterine fetal distress 	<ul style="list-style-type: none"> • Shallow irregular respiration • Poor muscle tone • Cyanosis disappears with stimulation or O₂ administration
Pulmonary Disease	<ul style="list-style-type: none"> • Parenchymal lung disease, pneumothorax, or pleural effusion • Diaphragmatic hernia • PPHN 	<ul style="list-style-type: none"> • Respiratory distress • Crackles and/or ↓ breath sounds on auscultation • Cyanosis improved or abolished with O₂ administration.
Cardiac Disease	<ul style="list-style-type: none"> • Cyanotic CHD with right-to-left shunt 	<ul style="list-style-type: none"> • Tachypnea (usually without retraction), lack of crackles or abnormal breath sounds (unless heart failure), Murmurs (may be absent) • Little or no increase in PaO₂ with O₂ administration

3- Heart Failure

Etiology

Table (31-2): Causes of Congestive Heart Failure in Neonates

A) Structural Heart Defects

At birth

- Hypoplastic left heart syndrome
- Severe tricuspid regurgitation (Ebstein anomaly)
- Pulmonary regurgitation
- Large systemic arteriovenous fistula

1st week of age

- TGA
- Premature infant with large PDA
- Total anomalous pulmonary venous return below diaphragm

1-4 weeks of age

- Critical aortic or pulmonary stenosis, coarctation of the aorta
- Common AV canal, VSD

B) Myocardial Diseases

- Myocarditis
 - ▶ Infectious (viral, bacterial or fungal)
 - ▶ Non infectious: Autoimmune diseases.
- Transient myocardial ischemia (with or without birth asphyxia)
- Cardiomyopathy (e.g., IDM)

C) Disturbances in HR

- SVT, atrial flutter or fibrillation, congenital complete AV block

D) Non-Cardiac Causes

- Birth asphyxia
- Metabolic (hypoglycemia, hypocalcemia)
- Severe anemia (e.g., hydrops fetalis)
- Overtransfusion or overhydration
- Neonatal sepsis

PDA: patent ductus arteriosus, AV: atrioventricular, IDM: infant of a diabetic mother, VSD: ventricular septal defect

Clinical manifestations

- Feeding difficulties and growth failure
- Tachypnea and tachycardia
- Pulmonary crackles or rhonchi
- Hepatomegaly
- Weak peripheral pulses
- Delayed capillary refill
- Cardiorespiratory collapse in severe cases
- Hydrops fetalis (intrauterine CHF)

4- Systemic hypoperfusion or shock

Neonates who present with shock within the first 3 wks of life are likely to have CHD with duct dependent systemic flow.

5- Arrhythmia (e.g., SVT or congenital heart block)

Evaluation of a Neonate with Suspected CHD

Clinical evaluation

- Examination (CHF, cyanosis, respiratory work, shock)
- Four-extremity BP assessments
- Systolic pressure in upper limbs is >10 mmHg than in lower limbs, suggests coarctation of the aorta, or interrupted aortic arch.
- Pulse oximetry for preductal/postductal O₂ saturation
 - ▶ Preductal > postductal O₂ saturation (differential cyanosis): PPHN or critical left-sided obstructive lesions
 - ▶ Postductal > preductal O₂ saturation (reverse differential cyanosis): TGA (with coarctation of aorta or interrupted aortic arch) or TGA (with supra-systemic pulmonary venous return).
- Hyperoxia test

Laboratory and imaging evaluation

- Arterial blood gases: hypoxemia & metabolic acidosis.
- Chest radiography for distinctive radiological signs.
- ECG, Echocardiography, and cardiac catheterization

Management of a Neonate with a Cardiac Problem

Neonates with cyanosis or shock

Once the diagnosis of critical CHD is made or suspected, the attention should be focused on the basic life support of the infant with maintenance of a PDA.

- Maintain a stable airway, adequate ventilation & oxygenation. If severe respiratory distress, profound cyanosis or apnea, immediately intubate the infant and initiate MV (sedation or neuromuscular blockade administration is recommended).
- Obtain vascular access including arterial line, better through the umbilical vessels.
- Maintain an adequate volume status (volume resuscitation for low cardiac output); however, excessive volume expansion may be potentially harmful.
- Correct metabolic acidosis.
- Initiate inotropic support: IV infusion of a combination of low-dose dopamine, up to 5 µg/kg/min & dobutamine 5-10 µg/kg/min.
- Initiate prostaglandin E₁ infusion for the neonate who fails a hyperoxia test or who has an equivocal result, as well as the neonate who presents in shock within the first 3 wks of life (continuous IV infusion, start with 0.05 µg/kg/min, and if no improvement increase the dose to 0.1 µg/kg/min).

Neonates with CHF

General measures

- Maintain adequate oxygenation.
- Restrict fluid intake (-30 ml/kg/day).
- Measure the infant's weight daily.
- Correct the predisposing factors (e.g., anemia, infection); for anemia, give packed RBCs to raise Hct ≥35%.

Drug therapy

- Diuretics (e.g. furosemide 1 mg/kg/dose q12 hrs IV).

- Afterload-reducing agents (captopril 0.1-0.4 mg/kg/dose, orally, 1-4 times a day).
- Inotropic agents: digoxin (used in non-critically ill infants and is contraindicated in hypertrophic cardiomyopathy, complete heart block, or cardiac tamponade).

N.B.: Supplemental O₂ should be given with caution in cyanotic infants in whom CHD is suspected; some physicians recommend holding O₂ administration in such cases, until PGE₁ infusion is initiated. Others recommend minimizing O₂ administration while keeping infant's SaO₂ as low as 75% until a diagnosis is established.

Patent Ductus Arteriosus (PDA)

Its incidence in preterm infants is inversely related to GA.

Clinical Manifestations

- Onset in preterm infants is usually 2-7 days after birth.
- Apneic spells/bradycardia may be the initial signs.
- Typically, a preterm infant with RDS shows some improvement during the first few days after birth. This is followed by an inability to wean the infant from the ventilator or a need to increase ventilator settings or O₂ requirements.
- The continuous murmur of a large PDA may not appear for 2-3 wks (instead, it is a systolic murmur with a slight or no diastolic component; best audible at the left infraclavicular area).
- Bounding peripheral pulses, hyperactive precordium, tachycardia with or without gallop rhythm, and wide pulse pressure.
- Symptoms and signs of CHF
- Poor weight gain

Investigations

- Chest x-ray: ↑cardiac shadow, pulmonary plethora/edema, prominent main pulmonary artery & left atrial enlargement
- Echocardiography

Management

- Initial management is usually conservative:

- ▶ Adequate oxygenation
- ▶ Fluid restriction
- ▶ Diuretics (furosemide)

This should not be given to the point of dehydration.

- In more symptomatic cases, indomethacin (prostaglandin antagonist) may be needed in premature infants. IV or oral ibuprofen (10 mg/kg initially, then 2 doses of 5 mg/kg after 24 and 48 hrs) may be used as an alternative therapy.
- Surgical ligation, if medical treatment is unsuccessful or contraindicated.

Persistent Pulmonary Hypertension of the Newborn (PPHN)

It mimics cyanotic heart diseases but with no underlying cardiac defect

Etiology (Table 31-3)

Clinical Manifestations

- Onset: 6-12 hrs after birth.
- Cyanosis and respiratory difficulties.
- Prominent right ventricle, single and loud S_2 , and soft regurgitant systolic murmur of tricuspid regurgitation & systemic hypotension
- PaO_2 gradient between a preductal (right radial artery) and a postductal (umbilical artery) blood >20 mmHg (or $>10\%$ difference in SO_2) is highly suggestive of ductal right to left shunt. In severe cases, differential cyanosis may be seen.

Investigations

- Chest x-ray films: usually normal or demonstrate pulmonary parenchymal disease.
- Echocardiography

Table (31-3): Causes of PPHN in Neonates

Pulmonary Vasoconstriction with Normally Developed Vascular Bed	↑Pulmonary Vascular Smooth Muscle Development	↓Cross-Sectional Area of Pulmonary Vascular Bed
<ul style="list-style-type: none"> • Alveolar hypoxia (e.g., MAS, RDS) • Birth asphyxia • Left ventricular dysfunction or shock • Infections (GBS) • Polycythemia 	<ul style="list-style-type: none"> • Chronic intrauterine asphyxia • Maternal use of prostaglandin synthesis inhibitors (e.g., aspirin) 	<ul style="list-style-type: none"> • Congenital diaphragmatic hernia • 1^{ry} pulmonary hypoplasia

MAS: meconium aspiration syndrome, RDS: respiratory distress syndrome, GBS: group B streptococci

Management

- Minimal handling, noise level & physical manipulation.
- O₂ administration (100%) to achieve postductal SaO₂ >95%.
- MV with FiO₂ 1.0, if previous measures fail.
 - ▶ Maintain adequate and stable oxygenation (SaO₂ >95%) using the lowest possible MAP.
 - ▶ Hyperventilation should, if possible, be avoided and PaCO₂ values should be kept >30 mmHg (at 35-40 mmHg) using mild hyperventilation.
- High-frequency oscillatory ventilator may be needed.
- Sedation and analgesia, fentanyl infusion (2-5 µg/kg/hr), or paralysis of the infant with pancuronium.
- NaHCO₃ infusion (0.5-1 mEq/kg/hr), to increase arterial pH to 7.50-7.55 (serum Na⁺ should be monitored).
- Inotropic therapy (e.g., dopamine, and dobutamine)
- Inhaled nitric oxide (NO): by MV in doses of 5-20 ppm.
- Sildenafil (phosphodiesterase type-5 inhibitor) at a dose of (0.3-1 mg/kg/dose q6-12 hrs PO) may be administered.
- Correct hypoglycemia, hypocalcemia & hypomagnesemia.

CHAPTER 32

Neonatal Shock

Hypotension

BP >2 SD **below** normal for age; the lower limit of the mean BP during the first postnatal day roughly = GA of the infant.

Shock

Inadequate circulatory perfusion of the tissues \rightarrow organ dysfunction and anaerobic metabolism \rightarrow lactic acidosis

Etiology

- Abnormal peripheral vasoregulation (e.g., proinflammatory cascades that cause vasodilatation).
- Hypovolemia
 - ▶ Blood loss
 - Antepartum: abruptio placenta, placenta previa, placental incision, fetofetal or fetomaternal transfusion
 - Postpartum: bleeding disorders, birth injury, liver laceration or adrenal hemorrhage, massive pulmonary hemorrhage
 - ▶ Plasma loss: sepsis and capillary leak syndrome
 - ▶ Extracellular fluid losses: excessive diuresis & skin loss
- Cardiac dysfunction (\downarrow cardiac output)
 - ▶ Myocardial dysfunction: birth asphyxia, infectious agents (bacterial or viral), hypoglycemia and hypocalcemia
 - ▶ Obstruction to cardiac blood flow
 - Inflow obstruction: tricuspid atresia, \uparrow intrathoracic pressure, or cardiac tamponade
 - Outflow obstruction: pulmonary atresia or stenosis, aortic atresia or stenosis, or critical aortic coarctation
 - ▶ Arrhythmias: if prolonged

Clinical Manifestations

- Tachycardia (not always in very premature infants)
- Pallor, poor skin perfusion, skin mottling & cold extremities
- Decreased urine output
- Hypotension and weak pulse
- Metabolic acidosis
- Lethargy

Investigations

- Hct, serum electrolyte levels, blood gases, and serum glucose level as soon as vascular access is obtained.
- Chest x-ray: a small heart in volume depletion and a large heart in cardiac disease.
- Specific studies to identify the cause
- Studies to detect sequelae (e.g., IVH & PVL in preterm infants)

Management

General

- Assess the infant and identify the cause: history taking, physical examination, chest x-ray and CVP measurement (if <3 mmHg, the infant is volume depleted, while if $>6-8$ mmHg, the infant probably has cardiogenic shock).
- Asphyxial shock
 - ▶ Treat respiratory failure with O_2 or MV.
 - ▶ Blood and volume expanders, if ever given, should be given with extreme caution.
- If still unsure of the cause, start empirical volume expansion with crystalloid (NS 10-20 ml/kg IV over 30 min).
 - ▶ If there is a response: continue volume expansion.
 - ▶ If there is no response: start an inotropic agent.
- Give supplemental O_2 or MV, as needed.
- CVP measurement
 - ▶ If CVP = 5-8 mmHg indicates improved cardiac output.

- ▶ If CVP >6-8 mmHg indicates that additional volume will usually not be helpful.
- Correct hypoglycemia, hypocalcemia, and electrolyte imbalance.
- Correct metabolic acidosis with NaHCO_3 infusion (1-2 mEq/kg), if base deficit ≥ 10 mEq/L (be sure the infant is receiving adequate ventilation and PaCO_2 is normal).
- Give inotropic agents: dopamine (6-30 $\mu\text{g/kg/min}$); add dobutamine (5-15 $\mu\text{g/kg/min}$) if dopamine fails to improve BP. Epinephrine may be used in infants who fail to respond to dopamine (start with 0.05-0.1 $\mu\text{g/kg/min}$, increase while decreasing dopamine infusion).

Specific situations

Hypovolemia

- Give IV crystalloid (colloids should be used with caution).
- In case of blood loss: give volume expanders until adequate tissue perfusion is attained (evidenced by good urinary output and CNS function). Send a blood sample to the laboratory for Hct value, and replace by packed RBCs, whole or reconstituted blood.
 - ▶ Hct <40%: packed RBCs, 5-10 ml/kg over 30-40 min
 - ▶ Hct >50%: normal saline or FFP
 - ▶ Hct 40-50%: alternating packed RBCs & NS transfusions
- Frequently monitor infant's vital signs & general condition.

Septic shock

- Obtain cultures (blood, urine and CSF); start or modify antibiotic therapy; if not already on antibiotics, start empiric therapy with IV ampicillin and gentamicin after obtaining culture specimens.
- Use volume expanders and inotropic agents, as needed.

Myocardial dysfunction

- Treat the underlying cause, and inotropic agents (contra-indicated in hypertrophic subaortic stenosis)

N.B.: Hydrocortisone (1 mg/kg q8-12 hrs for 2-3 days) may be used in extremely preterm infants with refractory hypotension.

CHAPTER 33

Common Congenital Anomalies

If one congenital anomaly is discovered, search for another

Cleft Lip and Cleft Palate

- Encourage breastfeeding in infants with isolated cleft lip.
- Use soft artificial nipples with large openings in cleft palate; syringe feeding is an alternative. If repeated life-threatening choking, consider NG tube feeding.
- Surgical closure is recommended before phonation:
 - ▶ Cleft lip at 3 months, when the infant has shown satisfactory weight gain and is free of infection
 - ▶ Cleft palate before 12 months

Choanal Atresia

- Unilateral choanal atresia: inability to pass a catheter into the nasopharynx during routine screening after delivery.
- Bilateral choanal atresia present in the DR with respiratory distress and cyanosis that resolves with crying.
- CHARGE association: **C**oloboma of the iris, choroid, and/or microphthalmia, **H**ear defect (e.g., ASD and/or conotruncal lesion), **A**tresia of choanae, **R**etarded growth and development, **G**enitourinary abnormalities (e.g., cryptorchidism, microphallus, and/or hydronephrosis), **E**ar defects with associated deafness.
- In bilateral cases, immediately insert an oral airway; the infant may be fed by gavage. Surgical correction should be done as soon as possible.

Esophageal Atresia (EA) and Tracheoesophageal Fistula (TEF)

- Clinical manifestations

- ▶ Excessive salivation, choking and coughing on feeding, or episodes of coughing, cyanosis & respiratory distress.
- ▶ H-type fistula usually presents by recurrent chest infection or respiratory distress related to meals.
- ▶ Inability to pass a catheter into the stomach.
- VACTERL association: **V**ertebral anomalies, **A**nal atresia, **C**ardiac defect (most often VSD), **T**racheo-**E**sophageal fistula with esophageal atresia, **R**enal dysplasia, **L**imb anomalies (most often radial dysplasia).
- X-ray studies: catheter coiled in the upper esophageal pouch. In complete atresia, no gas will be seen in the abdomen.
- H-type fistula can be demonstrated with administration of Omnipaque during cinefluoroscopy.
- Management
 - ▶ Maintain NPO.
 - ▶ Suction intermittently the proximal pouch.
 - ▶ Elevate the head of the bed 45 degrees.
 - ▶ Provide IV antibiotics for possible aspiration.
 - ▶ MV is to be avoided, if possible. If required, it should be done using a high rate and a low pressure.
 - ▶ Consult pediatric surgeon.

Diaphragmatic Hernia

- The most common site is the left hemithorax, 50% of cases are associated with other malformations.
- Clinical manifestations
 - ▶ Large defects present at birth with cyanosis, respiratory distress, scaphoid abdomen, decreased or absent breath sounds on the side of the hernia, & heart sounds displacement to the side opposite the hernia; intestinal sounds may be heard on chest auscultation.
 - ▶ Small hernias have a subtle presentation, manifested as feeding problems and mild respiratory distress.

Chapter 33: Common Congenital Anomalies

- Chest x-ray: loops of intestine in the chest.
- Management
 - ▶ Immediately intubate the infant after delivery; avoid bag and mask ventilation, nasal O₂ and mask.
 - ▶ Insert a large caliber NG tube and suction frequently or leave tube open below the level of the baby.
 - ▶ Sedate and give analgesia, as necessary.
 - ▶ Measure preductal and postductal SaO₂; avoid hypoxia and acidosis, and perform an echocardiography for estimation of pulmonary artery pressure.
 - ▶ Consult pediatric surgeon.

Omphalocele

- The covering sac may be intact or ruptured.
- Associated anomalies: Beckwith-Wiedemann syndrome (omphalocele, macrosomia & hypoglycemia), trisomies 13 and 18, and cardiac anomalies.
- Management
 - ▶ Provide continuous NG suction.
 - ▶ Apply saline-soaked sterile dressings immediately.
 - ▶ Maintain normal body temperature.
 - ▶ Maintain adequate hydration state.
 - ▶ Do not attempt to reduce the sac.
 - ▶ Start broad spectrum antibiotics.
 - ▶ Consult pediatric surgeon (when the baby stabilizes).

Gastroschisis

- The intestine is eviscerated with no covering sac.
- Management
 - ▶ Maintain normal body temperature.
 - ▶ Correct the hydration status.
 - ▶ Apply protective covering of the intestine by saline-soaked gauze, and dry sterile dressing.

- ▶ Start broad spectrum antibiotics.
- ▶ Consult pediatric surgeon (when the baby stabilizes).

Imperforate Anus

- Associated anomalies in 50% of cases (e.g., VACTERL, unilateral renal agenesis)
- Two categories
 - ▶ Low imperforate anus (with or without perineal fistula): at birth, the opening of the fistula is not always apparent, and an interval of 12-24 hrs may be required.
 - ▶ High imperforate anus: never associated with fistula in the perineum, but may be associated with rectovesical fistula in the male and rectovaginal fistula in the female.
- Erect x-ray upside down with a metal coin on the anal opening can help in the diagnosis of the level.
- Ultrasonography is helpful in locating the rectal pouch.
- Consult pediatric surgeon.

Myelomeningocele

- Examination of the skull is important to rule out associated hydrocephalus in type II Chiari defect.
- Facial cleft, heart malformations, & genitourinary tract anomalies are commonly associated anomalies.
- Perform chest radiographs to detect rib deformities and cardiac malformations; spine radiographs to detect vertebral anomalies, and x-ray hips to detect hip dysplasia.
- Order for serum creatinine (if voiding patterns are abnormal), ultrasonography (to assess possible structural abnormalities), urine culture (if UTI is suspected) and Brain CT, MRI and ultrasonography (to detect hydrocephalus).
- Management
 - ▶ Keep the newborn in prone position with a sterile saline moistened gauze sponge.

- ▶ Administer antibiotics (ampicillin and gentamicin IV).
- ▶ Refer immediately to the neurosurgeon.

Developmental Dysplasia of the Hip (DDH)

- Early diagnosis and treatment are essential; examination of the hips should be a routine screening test in any neonate.
- Ultrasonography is useful for diagnosis in high risk cases (it should be delayed until 1 month).
- Treatment includes positioning using a brace applied over the diapers or open surgical correction.

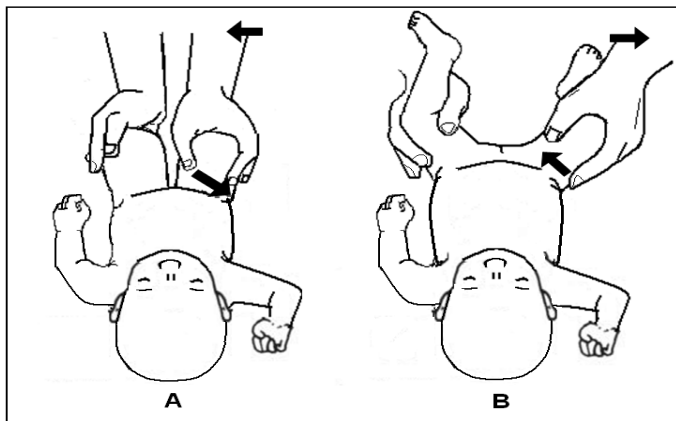


Figure (33-1): Maneuvers for developmental dysplasia of the hip

(A) Barlow (dislocation) maneuver: adduct the flexed hip and gently push the thigh posteriorly (+ve test → the hip will be felt to slide out of the acetabulum), with relaxing the proximal push, the hip can be felt to slip back into the acetabulum; (B) Ortolani test (reduction): grasp the infant's thigh between your thumb and index finger and, with the 4th and 5th fingers, gently lift the greater trochanter while simultaneously abducting the hip (+ve test → the femoral head will slip into the socket with a delicate “clunk” that is palpable but usually not audible).

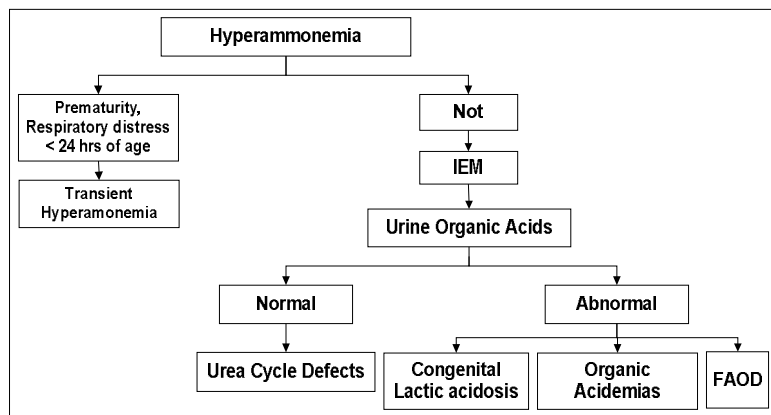
CHAPTER 34**Inborn Errors of Metabolism (IEMs)****Clinical Manifestations**

- Clinical features are usually nonspecific and may simulate infections and cardiopulmonary dysfunctions.
- A history of parental consanguinity, and unexplained neonatal deaths in the family.
- Two groups (based on timing and pattern of presentation).
 - ▶ Intoxication type: a newborn infant, who is born healthy and deteriorates clinically, after an initial symptom-free period, in an unexpected manner.
 - ▶ Energy deficiencies: an overwhelming neurologic illness without apparent symptom-free period.

Patterns of Presentation

- Neurological abnormalities (e.g., coma, encephalopathy).
- Metabolic acidosis with a high anion gap
- Hypoglycemia
- Hepatic manifestations (cholestasis and hepatomegaly)
- Dysmorphic features (e.g., coarse features, or macrocephaly)
- Cardiac diseases (cardiomegaly and arrhythmias)
- Abnormal urine and body odor
- Respiratory abnormalities (apneas, or irregular breathing)

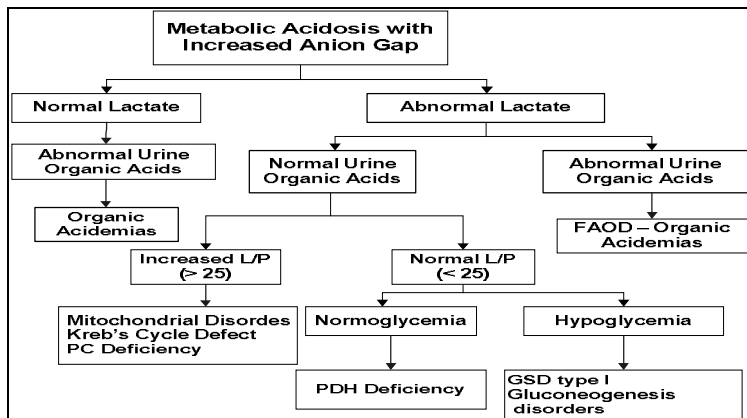
Approach to a Neonate with hyperammonemia



IEM: inborn error of metabolism, FAOD: fatty acids oxidation defects

Figure (34-1): Approach to neonatal hyperammonemia

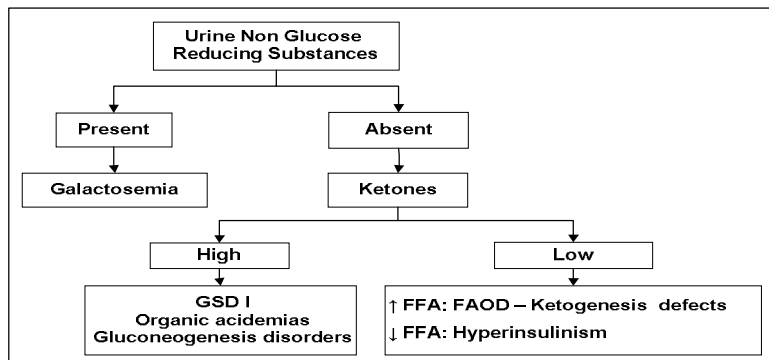
Approach to a Neonate with Metabolic Acidosis



L/P ratio: lactate/pyruvate ratio, FAOD: fatty acids oxidation defects, PC deficiency: pyruvate carboxylase, PDH: pyruvate dehydrogenase

Figure (34-2): Approach to neonatal metabolic acidosis

Approach to a Neonate with Persistent Hypoglycemia



FFA: free fatty acids, GSD I: glycogen storage disease type 1

Figure (34-3): Approach to a neonate with persistent hypoglycemia

Investigations

1st line laboratory studies

- CBC with differential
- Serum electrolytes, blood gases (calculate anion gap) and plasma urea and creatinine
- Blood glucose
- Plasma ammonia: use an arterial or uncuffed venous sample (no tourniquet), keep on ice and assay promptly
- Plasma lactate and pyruvate
- Liver function tests and coagulation profile
- Urine ketones and reducing substances

2nd line laboratory studies

- Plasma and urine amino acid analysis
- Plasma carnitine and acylcarnitine profile: ↑ in FAOD
- Plasma uric acid: ↑ in GSD 1
- CSF amino acids: ↑ CSF to plasma glycine in NKH
- Peroxisomal function tests: VLCFA's and phytanic acids

Specific diagnostic tests

- Enzyme assay
- Tissue biopsy, skin biopsy and fibroblast cultivation for specific enzyme testing
- DNA analysis for gene mutation

Management

Rescue treatment

- Stop oral intake and withhold all protein for 48-72 hrs, and until an aminoacidopathy, organic acidemias and urea cycle defects have been excluded.
- Maintain adequate calorie intake
 - ▶ At least >20% the ordinary needs. Give glucose 10-15% IV at a rate high enough (8-10 mg/kg/min); insulin may be required to keep the blood glucose level normal).
 - ▶ IV lipids are given only after ruling out FAOD.
- Correct dehydration, acidosis and hypoglycemia.
- Eliminate toxic metabolites.
 - ▶ L-Carnitine (25 mg/kg/dose q6 hrs): may be administered empirically in life-threatening situations associated with primary metabolic acidosis, hyperammonemia, or organic acidemias.
 - ▶ Sodium benzoate for hyperammonemia.
 - ▶ Peritoneal dialysis or hemodialysis: in cases of coma, hyperammonemia >500 mg/dl, intractable metabolic acidosis, or severe metabolic disturbances.
- Cofactor supplementation in cases of vitamin-responsive enzyme deficiencies: thiamine (200 mg/day), biotin (10 mg/day), vitamin C (100 mg/kg/day), riboflavin (100-300 mg/day), pyridoxine (50-500 mg/day) & hydroxycobalamin (20 mg/day).
- Treat the precipitating factors (e.g. infection).
- Monitor the infant clinically and biochemically.

- If clinical improvement is observed and a final diagnosis has not been established, provide some aminoacid intake after a maximum of 2-3 days of complete protein restriction (PO or IV, initial dose of 0.5 gm/kg/24 hrs and increase incrementally to 1 gm/kg/24 hrs, holding at that level until the diagnostic evaluation is complete).

N.B.: Ringer's lactate solution should NOT be used as a fluid/electrolyte therapy in any neonate with a known or suspected metabolic disorder.

Chronic therapy

- Dietary supplementation (e.g., cornstarch several times a day for infants with GSD).
- Special formulas (e.g., lactose free milk in galactosemia).
- Pharmacologic therapy (e.g., thiamine)
- Bone marrow or organ transplantation in some disorders.
- Enzyme replacement or gene therapies may be required.

CHAPTER 35

Developmentally Supportive Care

Components

- Limiting noises (minimize environmental noise, talk softly at the bedside, and discourage the use of the top of the incubator as a writing surface and/or storage area).
- Controlling light (cover the windows with screens, protect infant's eyes from bright light during care-giving, and dim the light at night).
- Positioning and nesting (use a soft blanket rolled into a nest, swaddle, provide containment during the procedures, and change infant's position every 4 hrs or at infant's status).
- Clustering of care.
- Minimizing painful procedures to those absolutely indicated.
- Gentle handling of the infant.
- Non-nutritive sucking by having the infant suckle on mother's emptied breast or a pacifier during gavage feeding.
- Kangaroo care
 - ▶ Infants appropriate for kangaroo care.
 - Infants should be physiologically stable with a body temperature of 36°C or higher.
 - If apnea or bradycardia is a problem, it must be self-resolving or require only minor stimulation.
 - Short sessions can begin during recovery when infant still requires medical treatment (e.g., low oxygen).
 - ▶ Initial management guidelines
 - Assess infant's temperature.

- All monitoring wires, IV lines and respiratory support tubes should be secured.
 - Undress the infant except for a diaper. A hat is not necessary unless the infant weighs <1,000 gm.
- Kangaroo positioning
 - Place the infant between the mother's breasts in an upright position.
 - Secure him/her with the binder firmly (the top of the binder is just under infant's ear). The hips should be flexed and abducted in a "frog" position and arms should also be flexed.
 - Make sure that the tight part of the cloth is over the infant's chest. Infant's abdomen should not be constricted and should be somewhere at the level of the mother's epigastrium.
- ▶ Monitoring
 - Monitor infant's vital signs & oxygenation status.
 - The infant should be returned to the incubator if any persisting signs of stress are identified.
 - The length of time is individually based and depends on the neonate's status and parental comfort.

Neonatal Pain Management

Nonpharmacological Approaches

- Environmental modification
- Swaddling, containment & facilitated tucking
- Massaging, holding & Kangaroo care
- Distraction by music, rhythmic rocking and soothing voice
- NNS (pacifier or non-lactating nipple)
- Sucrose 24-50% (0.1-2 ml orally), 2 min before procedure via syringe or pacifier, or glucose 30% (0.3-1 ml orally), 1-2 min before procedure

Pharmacological Approach

Table (35-1): Analgesic, Sedative, and Local Anesthetic Agents

Agent	Dose
Morphine Sulfate	<ul style="list-style-type: none"> • IV bolus: 0.05-0.1 mg/kg • IV infusion: 0.01-0.03mg/kg/hr
Fentanyl Citrate	<ul style="list-style-type: none"> • IV bolus: 0.5-3 µg/kg • IV infusion: 0.5-2 µg/kg/hr
Lidocaine	<ul style="list-style-type: none"> • 2-5 mg/kg subcutaneously • 0.5-1 mg/kg endotracheally
EMLA*	<ul style="list-style-type: none"> • 0.5-2 gm under occlusive dressing, 1hr before procedure
Ketamine	<ul style="list-style-type: none"> • IV bolus: 0.5-2 mg/kg • IV infusion: 0.5-1 mg /kg/hr
Thiopental Sodium	<ul style="list-style-type: none"> • 2-5 mg/kg IV
Midazolam	<ul style="list-style-type: none"> • IV: 0.05-0.15 mg/kg IV • IV infusion: 0.01-0.06 mg/kg/hr
Chloral Hydrate	<ul style="list-style-type: none"> • 0.25 mg/kg oral versed syrup • 25-75 mg/kg per dose orally or rectally
Phenobarbital	<ul style="list-style-type: none"> • Loading: 5-15 mg/kg • Maintenance: 3-4 mg/kg (PO, IV)
Acetaminophen	<ul style="list-style-type: none"> • 10-15 mg/kg orally • 20-30 mg/kg rectally

*Topical EMLA: EMLA, eutectic mixture of local anesthetic should be limited to a single dose/day and it must be removed within 2 hrs.

CHAPTER 36**Discharge Planning and Follow-Up****Discharge Criteria**

An infant is ready for discharge when the infant exhibits:

- Stable vital signs and temperature in an open crib for 24-48 hrs, particularly important when discharging LBW babies to their home in the winter
- An adequate weight gain
- A minimum discharge weight of 1,600-1,800 gm attained
- Ability to take all feeds by breast or bottle without any respiratory compromise
- Tolerating oral feedings or if long term plan is NG tube feedings, tolerating feedings and family has been trained
- Tolerating all medication administered orally
- Normal activity observed
- Normal laboratory values
- No apneas or bradycardias for 5 days
- Parents demonstrated ability to care for infant
- Arrangements made for primary and continuing care

Preparing the Family for Discharge

- Alter medication schedules to fit the family's schedule; eliminate unnecessary medications
- Change formulas and additives to less expensive or more easily obtained products.
- Include written information for the family to take home to use as reference and include several family members in the learning process.

Discharge Screening, Monitoring, and Examination

1- Hearing screening

- Auditory brain stem response (ABR) is done for all at risk babies; it is reliable after 34 wks' PMA.
- Repeat tests with abnormal results after 1 month and at 3 months.
- If an abnormal hearing screen is present, formal audiologic assessment should be performed.
- Infants at risk are those with:
 - ▶ Family history of childhood hearing loss
 - ▶ Birth weight <1,500 gm or babies <32 wks' gestation
 - ▶ Central nervous system insult (e.g., HIE, intracranial hemorrhage, seizures, meningitis, or encephalitis)
 - ▶ Otologic damage: hyperbilirubinemia, ototoxic drugs (e.g., aminoglycoside), PPHN, or hyperventilation.
 - ▶ Malformation of the ear or craniofacial anomalies

2- Eye examination (Refer to Chapter 23)

3- Cranial ultrasonography (Refer to Chapters 10 and 27)

4- Screening for congenital hypothyroidism

- It should be performed from 3rd - 7th day of life.
- Screening should not be missed in infants admitted to NICU in the first week of life.

5- Vaccination

- Infant should receive all vaccines according to his/her postnatal chronologic age regardless of his gestational age.
- Educate parents about vaccination schedule.

6- Discharge examination

- Heart: murmurs and femoral pulse
- CNS: activity and fullness of fontanelles
- Abdomen: urine output, stools, masses and hernias
- Skin: jaundice

- Cord: infection
- Infection: signs of sepsis
- Feeding: vomiting, weight gain, abdominal distension
- Joint: limited mobility, dislocations

Review of Hospital Course

- Perform a thorough review of the hospitalization.
- Review the results of diagnostic studies, such as cranial ultrasound examinations and echocardiograms.
- Subspecialty consultants should see the infant prior to hospital discharge.

Discharge Documentation

- Give the parents a follow up card.
- Arrange for follow up visits.
- Instructions (should be clear and precise):
 - ▶ Medications list, doses, and route of administration
 - ▶ Keeping the baby with the mother in the same room
 - ▶ On-demand breast feeding
 - ▶ Adjusting temperature in infant's room
 - ▶ Avoid taking the infant to crowded indoor places
 - ▶ Avoid contact with anyone who has a cold, flu, or other active infection
 - ▶ Avoid smoking around the infant
 - ▶ Encouraging anyone who comes into close contact with the infant to wash their hands
 - ▶ Care for umbilical cord
 - ▶ When to call your infant's doctor?
 - Any changes in infant's usual patterns of behavior (increased sleepiness, irritability or feeding poorly).
 - Breathing difficulties, blueness around lips, fever, vomiting or diarrhea, dry diaper >24 hrs, no stool >48 hrs, or black or red color seen in stools.

- Alarming signs of the umbilical stump: redness around umbilicus, unpleasant smell, discharge, or bleeding.

Follow-Up of High Risk Infants

- Birth weight <2,000 gm, GA <34 wks, IUGR
- Neurological problems
- Congenital infection or meningitis
- Respiratory problems (e.g., prolonged MV >7 days, or BPD)
- Hypoglycemia, polycythemia, or congenital anomalies

CHAPTER 37

Medical Records and Data Collection

The infant's medical record should include infant's data, parents' data, mother's obstetric history & resuscitation data.

Initial Assessment on Admission

- Measurement: weight, length & head circumference
- Vital signs (temperature, HR, RR, BP & capillary refill time)
- Full physical examination
- GA assessment: using new Ballard score, plot the growth parameters on the relevant curve against calculated GA and determine the baby's percentile.
- Write the provisional diagnosis.

Progress Sheet

- Vital signs
- Activity
- Measurements
 - ▶ Weight (measured daily and expressed as +ve or -ve grams from yesterday's recording), weight is measured and documented twice daily if infant <1,000 gm
 - ▶ Head circumference and length are measured weekly
 - ▶ Abdominal circumference is measured when needed
- Color: pallor, cyanosis, jaundice, plethora, or mottling
- Skin: cleanliness, rash, petechiae or ecchymotic patches, edema, sclerema, or any other abnormal signs
- System assessment
 - ▶ Respiratory system; examine for and comment on:
 - Downes' score: daily for infants with respiratory distress

- ☐ Air entry (bilaterally)
 - ☐ Apnea, bradycardia & desaturations: frequency, duration & measures needed to resume breathing
 - ☐ SaO₂, check if indicated
- ▶ Cardiovascular system: examine for and comment on:
 - ☐ Activity of the precordium
 - ☐ Heart sounds and murmurs
 - ☐ Peripheral pulsations
- ▶ Abdominal system; examine for and comment on:
 - ☐ Masses, or organomegaly
 - ☐ The umbilicus
 - ☐ Signs of feeding intolerance & intestinal sounds
- ▶ Neurological system; examine for and comment on:
 - ☐ Lethargy or irritability
 - ☐ Fontanelles
 - ☐ Reflexes (Moro and suckling), and tone
 - ☐ Seizures: type and frequency
- Check for bleeding from any orifice.
- Assess the hydration status daily (or twice daily if infant <1,000 gm) and classify the baby as well hydrated, dehydrated, or overloaded via the following parameters:
 - ▶ Weight change from yesterday
 - ▶ Vital signs, eyes, fontanelles, skin turgor and tongue
 - ▶ Urine volume, specific gravity & presence of glucosuria
 - ▶ Serum Na⁺ & Hct level
- Check IV cannula site for cleanliness, skin infection, sloughing, or extravasation.
- Investigations
 - ▶ CBC with differential, CRP, serum glucose, Na⁺, K⁺, Ca⁺⁺, BUN and creatinine
 - ▶ If indicated, serum bilirubin, blood gases & liver enzymes
 - ▶ Chest x-ray for babies suffering from respiratory distress
 - ▶ Cranial sonar or echocardiography, if indicated

- ▶ Assessment of feeding and growth: serum Ca^{++} , pH, alkaline phosphatase weekly & serum albumin monthly
- Infection data
 - ▶ Infant's temperature
 - ▶ Poor activity, poor Moro and suckling reflexes, or mottling
 - ▶ CBC, CRP
 - ▶ CSF analysis
 - ▶ Culture and sensitivity
- Treatment sheet
 - ▶ Total fluids.....ml/kg/day, giving..... kcal/kg/day
 - ▶ Enteral fluids..... ml/kg/day, giving.....kcal/kg/day
Document type, route, amount/feed & frequency
 - ▶ Parental nutrition..... ml/kg/day, giving..... kcal/kg/day (via peripheral IV line or UVC)
 Na^{+} mEq/kg/day - K^{+} mEq/kg/day - Ca^{++} mg elemental ca/kg/day - GIR..... mg/kg/min
 - ▶ Incubator temperature referring to NTE ranges
 - ▶ Oxygen mode and flow in liter/min: if the baby is on CPAP or MV, fill the relevant flow sheet.
 - ▶ Drugs
 - 1st line antibiotic treatment: ampicillin & gentamicin.
 - Write generic and trade names.
 - Prescribe the dose accurately based on actual weight.
 - Mention frequency, route of administration, and duration.
 - State precautions, if needed.
 - ▶ Nursing care
 - Suction and physiotherapy
 - Checking feeding intolerance signs
 - ▶ Instructions to the parents

CHAPTER 38

Procedures

Hand Washing

Simple Hand Washing

- Wash with soap or detergent for 30 seconds (longer, if hands are visibly soiled).
- Push wrist watch and long uniform sleeves above wrists.
- Remove jewelry (except a plain band).
- Keep fingernails short and filed.
- Stand in front of the sink, keeping hands and uniform away from sink surface and turn on water. If hands touch the sink during hand washing, repeat the process.
- Avoid splashing water on uniform.

Antiseptic Hand Washing

- Wet hands and lower arms (2.5 cm below the elbow) thoroughly under running water. Keep hands and forearms lower than elbow level during washing.
- Apply 3–5 ml of povidone-iodine solution to the cupped hands and carry out steps 1–6 (2–3 min). Each step consists of 5 strokes backward and forward.
- Rinse hands and wrists thoroughly (keeping hands down and elbows up).
- Dry hands thoroughly with good quality paper towels from fingers up to wrists and forearms, and then discard paper towel in proper receptacle.
- Turn off water with foot or knee pedals, and hold the hands up and away from clothing.

Alcohol hand-rub technique (with ethanol 70%)

- The hands and fingers are rubbed together with ethyl-alcohol 70% until dry.
- This method can be applied in situations where there is no gross soiling of the hands, where a sink is not readily available, or during an outbreak of infection.

Surgical Hand Washing

- Remove any jewelry on hands and wrists and turn on the water and ensure that it is warm and the flow is moderate.
- Wet and lather hands and forearms (5 cm above the elbow) with the povidone-iodine solution. Keep hands above level of elbows during the entire procedure.
- With hands under running water, clean under nails with nailbrush. Discard brush after use.
- The same hand washing steps with the wrist and forearm being included for a period of 3 - 5 min.
- Rinse hands and arms thoroughly under running water. Remember to keep hands above elbows.

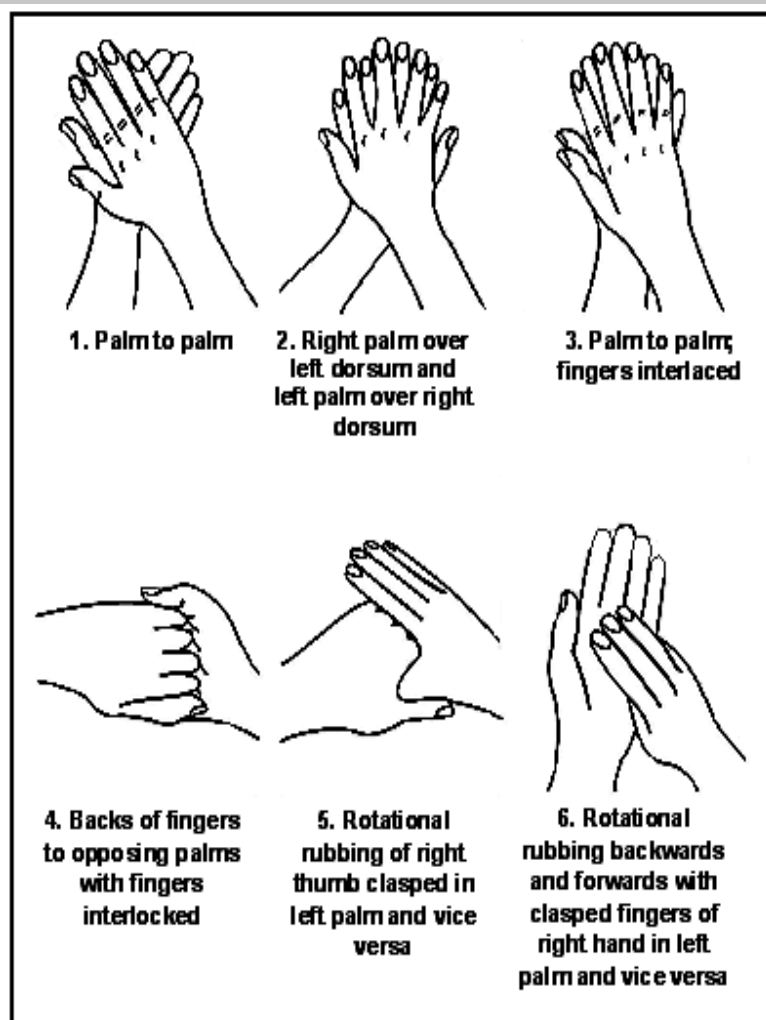


Figure (38-1): Hand washing and disinfection technique

Peripheral IV Line Placement

Equipment

70% alcohol swabs - tourniquet or elastic rubber band - over-the-needle cannula (sizes 22 & 24 gauge) - connection for cannula/IV tubing – gauze – saline – syringes – tape – arm board - scissors

Technique

- Avoid areas adjacent to injured skin or infection.
- Differentiate veins from arteries (palpate for arterial pulsation and evaluate during occlusion [limb arteries will collapse and veins will fill; scalp arteries fill from below and veins fill from above]).
- Restrain the extremity on an arm-board, or have an assistant holding the extremity. Apply a tourniquet proximal to the puncture site. If a scalp vein is to be used, shave the area; a rubber band can be placed just above the eyebrows.
- Select a straight segment of the vein, and prepare the site with alcohol and allow drying.
- Attach a saline filled syringe to the needle, fill the needle with flush, then remove the syringe.
- Pull the skin taut, hold the needle parallel to the vessel in the direction of blood flow, introduce through the skin a few millimeters distal to the point of entry into the vessel, and insert until blood appears in the cannula (arterial blood is bright red and venous blood is darker). Withdraw the stylet while advancing the cannula.
- Remove the tourniquet, and then infuse a small amount of saline to confirm the position. Observe for possible skin blanching or swelling.
- Secure the cannula in place with adhesive tape. Write date, time, and cannula size on the piece of tape secured to site.

Intravenous Line Management

- Document the type of fluid and the hourly rate.
- Observe the insertion site for signs of infiltration and irritation.
- Change IV tubing and fluids every 24 hrs.
- Change peripheral cannula every 3 days.

Complications

Hematoma, venospasm, phlebitis, infiltration of subcutaneous tissue, infection, embolization, and accidental injection or infusion into an artery

Key Points

- Peripheral cannulation is an invasive technique
- Securing the cannula in place is as important as its insertion
- The skin covering the tip of the cannula should not be covered with an opaque substance.

Capillary Blood Sampling

Equipment

Gloves - sterile lancet - alcohol swabs or cotton-wool ball soaked in antiseptic solution - dry cotton-wool ball - sterile 2×2 gauze pads - heparinized glass capillary tubes

Procedure

- Wrap the foot in a warm cloth ($\leq 40^{\circ}\text{C}$) for 5 min (optional).
- Prepare skin of the heel using an alcohol swab and allow drying.
- Flex the foot up towards the leg and hold it in this position with one hand and encircle the heel with the palm and index finger. Squeeze the heel firmly enough to make it flush red (but not so much that it turns white), then puncture the skin (about 1-2 mm deep) firmly with a lancet.
- Wipe off the 1st drop of blood and place the capillary tube at the site of the puncture. Squeeze gently and intermittently and **avoid** excessive squeezing and rubbing.

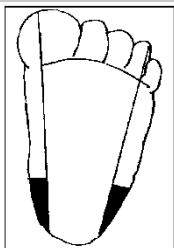


Figure (38-2): Site for heel prick (shaded areas)

- One end of the heparinized capillary tube is touched to the drop of blood. The tube is held at about 20° angle from horizontal. Allow enough time for capillary refill; both ends of the tube should remain unplugged during the collection; the tube should be filled as completely as possible.
- Once the tube is full, the free end is occluded with a gloved finger. Cap ends of the tube gently with clay.
- Apply pressure to the puncture site with a dry cotton-wool ball or sterile gauze pad for several minutes.

Complications

Cellulites, osteomyelitis, scarring, and pain

Arterial Blood Sampling

Equipment

Gauge scalp vein needle (23-25) or gauge venipuncture needle (23-25) - syringe (1 or 3 ml) - povidone-iodine and alcohol swabs - gauze pad (4×4) - gloves - heparin 1:1000

Procedure

- Draw a small amount of heparin into the syringe and then discard any excess heparin.
- Radial artery is the most frequently used; alternatively posterior tibial or dorsalis pedis arteries. Avoid femoral and brachial arteries.

- Allen test:
 - ▶ Elevate the arm and simultaneously occlude radial and ulnar arteries at the wrist. Rub the palm to cause blanching.
 - ▶ Release pressure on the ulnar artery:
 - Normal color returns in the palm in <10 seconds → adequate collaterals.
 - Normal color does not return in ≥15 seconds → do not use this arm, and check the other arm.
- Take the infant's hand in your left hand and extend the wrist. Palpate the radial artery with the index finger. Mark the puncture site with a fingernail imprint.
- Clean the puncture site with a povidone-iodine swab and then with an alcohol swab.
- Puncture the skin at ≈ 30° angle, and slowly advance the needle with the bevel up until blood appears in the tubing.
- Collect the least amount of blood needed for the test.
- Withdraw the needle and apply firm but not occlusive pressure to the site for ≥5 min with a gauze pad.
- Expel air bubbles from the sample & tightly cap the syringe.
- Place the syringe in ice, and take it to the laboratory immediately. Note the collection time and the infant's temperature and hemoglobin on the laboratory slip.

Complications

Hematoma, embolism, infection, and inaccurate results (excess heparin → falsely ↓pH & PaCO₂, air bubbles → falsely ↑PaO₂).

Blood Glucose Monitoring

Equipment

Gloves – fresh reagent strips - micro lancets - container for sharps - clock or watch - alcohol swabs - cotton wool swab to stop the bleeding - sterile 2×2 gauze pads - adhesive bandages (optional)

Procedure

- Clean the area thoroughly with alcohol swabs & allow drying.
- Encircle the heel with the palm of your hand and index finger, then make a quick, deep (<2.5 mm) puncture with a lancet on the most medial or lateral portions of the plantar surface. Avoid repeated sampling at previous puncture sites.
- Remove the 1st drop of blood with a gauze pad, gently squeeze the heel, and collect the subsequent large drop of blood on the reagent strip.
- Maintain pressure on the puncture site with a dry sterile gauze pad until the bleeding stops. Use an adhesive bandage, if necessary.

Remember

- Reagent strips must be:
 - ▶ Fresh and stored at room temperature, not in a fridge.
 - ▶ Kept away from direct sunlight.
 - ▶ Discarded if the expiry date has been reached.
- A large drop of blood is needed.
- Blood must be wiped off after exactly 60 seconds by using a clock or a watch with a second hand.
- Do not attempt to wipe, wash off, or rub off any pieces of adherent, dry blood on the strip.

Umbilical Vessel Catheterization

Umbilical Artery Catheterization

Equipment

Sterile gown and gloves - antiseptic solution - surgical drape with central aperture - umbilical catheter (size 3.5-5Fr) - three-way stopcock - syringe 10 ml - saline flush solution (saline with heparin, 1-2 U/ml) - scissors - tape measure - umbilical tie - gauze sponge - two curved mosquito hemostats - toothed iris forceps - two curved, non-toothed iris forceps - 3-0 silk suture on small curved needle

Technique

Catheter insertion

- ▶ Determine the appropriate length of catheter to be inserted (**Figure 38-3**). Another option is to calculate the insertion distance using the following formula:

$\text{High UAC distance (cm)} = (\text{Birth weight (kg)} \times 3) + 9$

- Follow sterile technique
 - ▶ Scrub hands to elbow for 3 minutes.
 - ▶ Put on sterile gloves, a mask, a hat, and a sterile gown.
 - ▶ Cleanse the cord & surrounding area with povidone-iodine.
 - ▶ Drape the abdomen with sterile towels leaving the feet and head exposed.
- Place umbilical tape around the base of the cord and tie loosely with a single knot, then cut the cord horizontally with a scalpel to a length of 1 cm from skin.
- Dilate the vessel
 - ▶ Remove clots with forceps
 - ▶ Identify cord vessels
 - Vein: large, thin-walled, sometimes gaping, most frequently situated at the 12 O'clock position).
 - Arteries: smaller, thick-walled, usually located at the 4 and 7 O'clock positions; they are white and may protrude slightly from cut surface.
 - ▶ Grasp cord stump to hold it upright and steady, using toothed forceps at point close to (but not on) the vessel to be catheterized.
 - ▶ Gently dilate the vessel by inserting iris forceps into the lumen to a depth of 0.5 cm and leave them in place for a minute after the release of tension on the forceps.
- Insertion of the catheter
 - ▶ Place a sterile, saline-filled catheter into the vessel to the calculated length (low catheterization "catheter tip lies below

the level of L3"- high catheterization "catheter tip lies above the diaphragm at the level of T6 to T9").

- ▶ A good blood flow should be noted through the catheter.
- ▶ Verify the position of the catheter by x-ray before use.
- ▶ If the catheter tip is above required position, measure distance between actual and appropriate position on the radiograph and withdraw equal length of catheter. Then repeat the radiographic study. If the catheter tip is below the required position, remove the catheter (**never advance it once in situ**).
- Fix the catheter by placing a purse-string suture using silk thread around base of the cord (not through skin or vessels) and add a tape bridge for further stability.
- Add dilute heparin, 0.25 unit/ml of infusate.

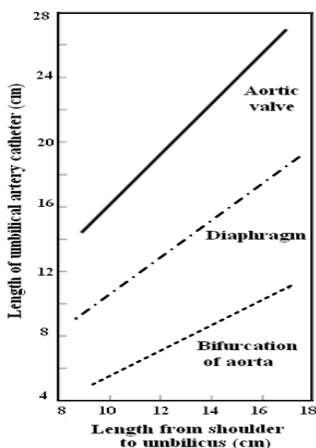


Figure (38-3): Umbilical artery catheter placement

To determine catheter length, measure (in centimeters) a perpendicular line from the top of the shoulder to the umbilicus. This determines the shoulder-umbilical length. Plot this number on the graph to determine the proper catheter length for the umbilical artery catheter. It is helpful to add the length of the umbilical stump to catheter length (Dunn PM: Localization of the umbilical catheter by postmortem measurement. Arch Dis Child 1966; 41:69).

N.B.: UAC should not be left in place for >5 days.

Complications

Bleeding, infection, thromboembolism, vessel perforation, vasospasm, and hypertension

Catheter removal

Slowly remove the catheter over 30-60 seconds to allow the umbilical artery to constrict at its proximal end while the catheter is still occluding the distal end.

Umbilical Vein Catheterization

Equipment

Prepare the same equipment as for UAC, except using a No. 6Fr catheter for infants weighing <3.5 kg, and a No. 8Fr catheter for those weighing >3.5 kg.

Technique

Similar to umbilical artery catheterization

- Determine the specific length of catheter (**Figure 38-4**). Another method is to measure the length from the xiphoid to the umbilicus and adding 0.5-1 cm. If the catheter is placed for an exchange transfusion, it is advanced only as far as it is necessary to establish good blood flow (\approx 2-5 cm).
- In case the catheter enters the portal vein (suspected if a resistance is met and the catheter cannot be advanced to the desired distance, or if a bobbing motion is detected).
 - ▶ Try injecting flush as you advance the catheter.
 - ▶ Pass another catheter (a smaller size) through the same opening and then remove the one in the portal system.
 - ▶ Apply mild manual pressure in the right upper quadrant over the liver.
- **Only** isotonic solution is infused until the position of the catheter is confirmed by x-ray films.

- **Never** advance a catheter once it is secured in place.
- UVC should be removed as soon as possible when no longer needed, but can be used up to 14 days if managed aseptically.

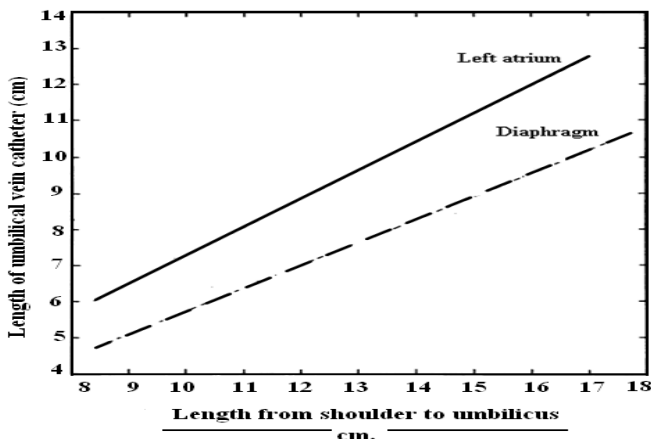


Figure (38-4): The umbilical venous catheter placement

Determine the shoulder-umbilical length as for the umbilical artery catheter. Use this number to determine the catheter length using the graph. Remember to add the length of the umbilical stump to the length of the catheter (Dunn PM: Localization of the umbilical catheter by post-mortem measurement. Arch Dis Child 1966; 41: 69).

Complications

Infection, thromboembolism, hepatic necrosis (catheter in the portal system), arrhythmias, and portal hypertension

Contraindications of Umbilical Vessel Catheterization

Vascular compromise in lower limbs or buttock areas, peritonitis NEC, omphalitis, omphalocele, and acute abdomen etiology

Remember

- Do not use topical antibiotic ointment or creams on umbilical catheter insertion sites.
- Replace UVC, if the catheter malfunctions.

- Remove and do not replace UVC if any signs of catheter related blood stream infection (CRBSI) or thrombosis are present.
- Remove and do not replace UAC if there are any signs of CRBSI, vascular insufficiency, or thrombosis.
- Remove umbilical catheters as soon as possible when no longer needed or when any sign of vascular insufficiency to the lower extremities is observed.

Exchange Transfusion

Indications

- Hyperbilirubinemia when phototherapy fails to prevent rise in bilirubin to toxic levels (**Refer to Chapter 17**).
- Hemolytic disease of the newborn if:
 - ▶ Cord bilirubin level is >4.5 mg/dl & cord Hb level <11 gm/dl
 - ▶ Hb level is between 11-13 gm/dl.
 - ▶ Bilirubin increasing >1 mg/dl/hr despite phototherapy.
- Hydrops fetalis due to hemolytic diseases.
- Partial exchange transfusion for treatment polycythemia.

Equipment

Sterile gown & gloves - sterile towels - radiant warmer equipment for resuscitation - cardiopulmonary monitor - equipment for umbilical artery & vein catheterization - blood filter - IV tubings (one between donor blood and stopcock, and the other between stopcock and collection container) - plastic bag or container - two sizes 3-5 ml syringes for laboratory samples - appropriate blood product - syringes and tubes for exchange blood tests

For pull-push method: One 4-way stopcock (or two 3-way stopcocks connected) - syringes 5, 10, 20 ml

For continuous method: Three “3-way” stopcocks - one 50-60 ml syringe for each 150 ml of blood to be withdrawn - one 50-60 ml syringe for the infusion of blood - one 5 ml syringe for a heparinized saline flush

Preparation for Exchange Transfusion

- Send the maternal and infant blood for cross matching.
- Prepare type of blood for exchange transfusion:
 - ▶ Rh incompatibility: Rh-ve blood (cross-matched with the mother's blood if prepared before delivery; it may be also cross matched with the infant if obtained after delivery).
 - ▶ ABO incompatibility: O+ve or O-ve group (cross-matched with both the infant's and mother's blood).
 - ▶ Other cases: infant's group after cross-matching with the infant's blood.
- Use only fresh (<72 hrs old) citrated blood.
- Establish and document baseline vital signs.
- Don't give anything orally for 3-4 hrs prior to the procedure. Place a NG tube and leave it in place.

$$\text{Volume of blood for exchange (ml)} = 80 \text{ ml} \times \text{weight [kg]} \times 2$$

- Mix the blood well by hanging it upside down for 20-30 min, then check the Hct (should be between 45% and 55%).
- Use no more than equivalent of one whole unit of blood for each procedure.
- Warm the blood to a temperature of 37°C; either by placing the tubing in a blood warmer with a precise thermostatic control or by immersing the tubing in a warm water bath of 37-38°C (do not warm the blood under the radiant warmer).
- Put the infants under a servo-controlled radiant warmer.
- Infant's arms and legs should be properly restrained (snug but not tight).
- A nurse must be available to constantly monitor the infant's condition, perform any necessary interventions, and record blood volume removal & infusion on the Flow Sheet
- Soften old dried umbilical cord with saline-soaked gauze.

- If using the pull-push method, UVC must be inserted only as far as required to permit free blood exchange (2-5 cm). In this case, avoid infusing drugs such as calcium.
- If using the continuous method UAC & UVC and/or a 23-gauge peripheral IV can be used.
- Assure proper placement of the catheter by easily aspirating blood through it.
- The procedure will take from 1-2 hrs.

Pull-Push Method

- Withdraw or infuse blood in aliquots tolerated by the infant
 - ▶ 5 ml for infants <1,500 gm
 - ▶ 10 ml for infants 1,500-2,500 gm
 - ▶ 15 ml for infants 2,500-3,500 gm
 - ▶ 20 ml for infants >3,500 gm
- Whether withdrawing or infusing, the same amount of blood should always be handled.
- Follow the steps illustrated in **(Figure 38-5)**.
- The orientation of the stopcock(s) for infusion and withdrawal must be double-checked by the assistant.
- Avoid rapid shifts in blood volume by slowly and steadily removing the infant's blood and infusing donor blood at a rate of ≈ 1 cycle/minute until the desired blood has been exchanged.
- Gently shake the blood bag every 10-15 min.

Continuous (Isovolumetric) Method

- A 3rd member should be available.
- Follow the steps illustrated in **(Figure 38-6)**
- Infuse donor's blood (2-3 ml/kg/min) until 50 ml are infused.
- Gently shake the blood bag every 10-15 min.
- Withdraw infant's blood (2-3 ml/kg/min) until 50 ml are withdrawn.
- Change the 50-60 ml syringe periodically with a new one & gently flush the catheter with 1-2 ml heparinized (5 unit/ml) saline.

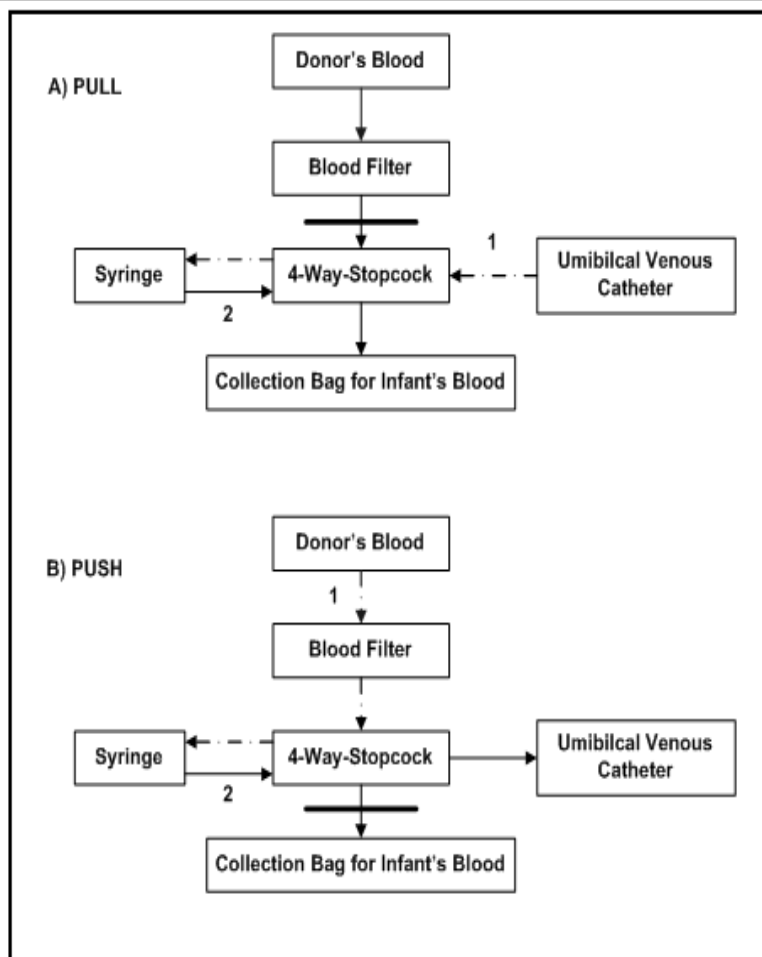
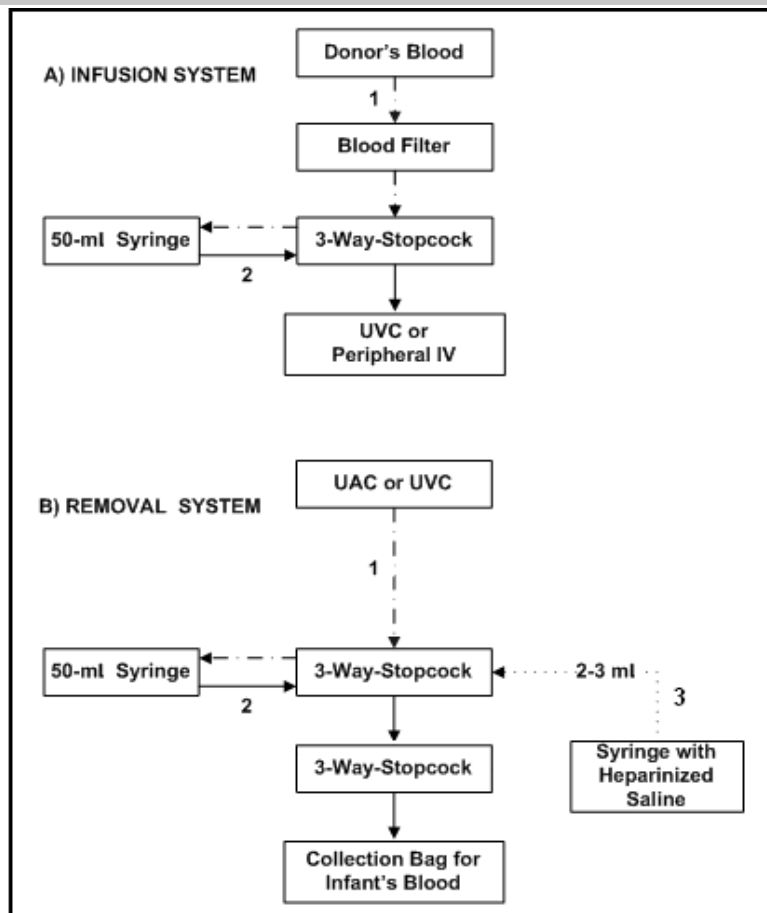


Figure (38-5): Schematic approach to Pull-Push method of exchange

- A) Pull: 1) Blood is withdrawn from infant 2) Blood is discarded into collection bag
 B) Push: 1) Donor's blood is withdrawn from the blood bag 2) Donor's blood is injected into the infant.



UAC: Umbilical artery catheter, UVC: Umbilical vein catheter

Figure (38-6): Schematic approach to continuous method of exchange

A) Infusion system: 1) Donor's blood is withdrawn from the blood bag, 2) Donor's blood is injected into the infant.

B) Removal system: 1) Blood is withdrawn from infant 2) Blood is discarded into collection bag 3) Periodically flush the catheter with 1-2 ml of heparinized saline.

During and After Exchange Transfusion

- Before starting, withdraw 5-10 ml blood to check bilirubin, Hct, electrolyte and calcium levels.
- Check infant's temperature, oxygenation & other vital signs every 15 min & blood glucose value every 30 min.
- Administer 1-2 ml of 10% calcium gluconate by slow infusion after 100 ml of exchange donor blood.
- Observe the infant for signs of hypocalcemia (e.g., jitteriness, twitches, apnea, or seizures). If noted, flush the catheter with normal saline, and give 100-200 mg calcium gluconate 10% (i.e., 1-2 ml/kg/dose) slowly through a peripheral IV line.
- When the desired amount of blood has been exchanged, send an infant's blood sample to the laboratory for glucose, bilirubin, Hct, electrolyte and calcium levels and cross-matched for possible future exchanges.
- Check Bilirubin levels every 4-6 hrs until adequate levels are achieved or an additional exchange transfusion is needed.
- Re-institute phototherapy and check vital signs every 15-30 min for 3-4 hrs, or until stable.
- Resume oral feedings 2-3 hr after completing the exchange.
- Consider antibiotic prophylaxis, if a dirty cord was entered or there was a break in sterile technique.

Complications

- Hypocalcemia, hypo- or hyperglycemia, hyperkalemia
- Apnea, bradycardia, hypotension, hypertension, arrhythmia
- Thrombocytopenia, neutropenia, and DIC
- Catheter-related: vasospasm, thrombosis, embolization
- Feeding intolerance, ischemic injury and NEC
- Omphalitis, septicemia, HIV, CMV and hepatitis
- Hypothermia and hyperthermia
- Rash with or without graft versus host disease (GVHD)

Suprapubic Bladder Aspiration

Equipment

Sterile gloves - povidone-iodine solution - 23 or 25 gauge needle with a 3 ml syringe attached - gauze pads (4x4) - sterile container

Procedure

- Be sure that voiding has not occurred within the previous hour. An assistant holds infant's legs in a frog-leg position.
- Put on sterile gloves, and clean the skin at the puncture site with antiseptic solution three times.
- Palpate the pubic symphysis and insert the needle 1-2 cm above the pubic symphysis in the midline at a 90° angle.
- Advance the needle while aspirating at the same time. Do not advance the needle once urine is seen in the syringe.
- Withdraw the needle & maintain pressure over the puncture site.
- Transfer the specimen to a sterile urine cup.

Complications

Bleeding (check platelet count before the procedure), infection & bowel perforation

Lumbar Puncture

Equipment

Three sterile specimen tubes - sterile drapes - gloves - sterile gauze - lidocaine 1% - povidone-iodine solution - 22-24 gauge spinal needle with stylet - 1 ml syringe

Procedure

- Positioning: either a sitting or a lateral decubitus position. An intubated, critically ill infant must be placed in the lateral decubitus position. The assistant should hold the infant firmly at the shoulders and buttocks so that the lower part of the spine is curved. Neck flexion should be avoided.

- Use supplemental O₂ before the procedure.
- Site: the space between the 4th and 5th lumbar processes.
- Palpate the iliac crest and slide your finger down to L4 vertebral body and make a nail imprint at the exact location.
- Put gloves on and clean the lumbar area with antiseptic solution, starting at the selected interspace (a widening circle from that interspace up and over the iliac crest).
- Drape the area with one towel under the infant and one towel covering everything but the selected interspace; keep the infant's face exposed. Inject 0.1-0.2 ml of 1% lidocaine SC (optional).
- Insert the needle in the midline into the selected site. Advance the needle slowly in the direction towards the umbilicus, withdrawing the stylet frequently to check for the appearance of spinal fluid. Usually a slight “pop” is felt as the needle enters the subarachnoid space.
- Collect ≈ 1 ml of CSF in each of the 4 sterile specimen tubes by allowing the fluid to drip into the tubes.
- Replace the stylet and withdraw the needle, and maintain pressure on the area.
- Send 4 tubes of CSF to the laboratory.
 - ▶ Tube 1: Gram's stain, culture, and sensitivity testing.
 - ▶ Tube 2: glucose and protein levels.
 - ▶ Tube 3: cell count and differential.
 - ▶ Tube 4 (optional): rapid antigen tests for specific pathogens
- If a bloody specimen is obtained in the 1st tube, observe for clearing in the 2nd and 3rd tubes:
 - ▶ If bleeding clears; the tap was traumatic.
 - ▶ If blood doesn't clear but forms clots; repeat the tap.
 - ▶ If blood doesn't clear & doesn't clot; IVH should be considered.

Complications

Infection, herniation of cerebral tissue, spinal cord and nerve damage, apnea/bradycardia, and hypoxia

Blood and Blood Products Transfusion

Indications

Red blood cell transfusion (Refer to Chapter 30)

Fresh frozen plasma transfusion

- Coagulation deficiencies (when the specific factor is not available)
- Volume expansion in the presence of abnormal coagulation
- Protein C deficiency, protein S deficiency and purpura fulminans

Platelets transfusion

- A healthy term infant with platelet count 20,000-30,000/ μL
- Ill neonates with platelet count <20,000-50,000/ μL
- Infants receiving indomethacin with platelet count <75,000/ μL
- Therapeutic transfusions for infants whose count <100,000/ μL and undergoing major surgery or with acquired or congenital qualitative platelet abnormalities

Transfusion Procedure

- Write transfusion orders & obtain consent from the parents.
- Check the blood for name, type and Rh, medical record number, and expiration date (with another personnel).
- When a large volume of blood is to be transfused, warm it 1st. Never submerge the bag in a hot water or place under a hot light.
- Draw blood to be administered through a blood filter and administer by direct drip or via a syringe pump.
- Do not use mechanical pumps for the transfusion of RBCs. Filter FFP, cryoprecipitate, and platelets before giving. Draw through a filter, if using a syringe pump.
- Place the infant on a cardiac monitor during transfusion.
- Record vital signs according to the following schedule:
 - ▶ 15 minutes before the transfusion
 - ▶ Once each hour during the transfusion
 - ▶ 1 hour after the transfusion

- Observe the infant for any signs of a transfusion reaction. Return the blood product bag to the laboratory following a reaction.
- Document transfusion information in the infant's chart.
- Consider a dose of IV furosemide after transfusion in a fluid sensitive infant.
- If parenteral glucose is interrupted during blood transfusion, check blood glucose every hour during transfusion. Temporarily discontinue transfusion to deliver glucose if the blood sugar <45 mg/dl. Check blood glucose for 30-60 min after transfusion.
- Check the IV site every 15 min for redness & edema.
- Obtain a follow-up Hct 4-6 hrs after transfusion.

Preparation for Transfusion

- Obtain a blood sample to cross match the infant's blood. Send 2 ml in an EDTA tube with every request for cross-matched products (specimens are appropriate for only 72 hrs).
- For other blood products, call blood bank to check if the infant's blood group and type is on record. If a record of the infant's blood group does not exist, send 2 ml EDTA blood.

Safety Technique

- Before drawing the specimen, prepare a label with the infant's name and medical record number printed legibly.
- Confirm the accuracy of the name and number on both the label and the infant's chart.
- If any correction is required, write a new label.
- At the bedside, after drawing the blood, attach the label to the tube. **Do not** leave the infant's bed without attaching the label to the tube. The nurse or physician who drew the blood from the infant should sign the label.

Intravenous Access

- The IV catheter must be at least a size 23 gauge.

- Do not transfuse any blood product via arterial lines or umbilical artery catheters. Platelets should be administered through a peripheral venous access.
- Do not infuse parenteral nutrition (or any glucose containing fluids) along with the transfusion via the same line.
- Never add any drug or IV fluid to blood or blood product.
- Flush the IV with saline after the transfusion is completed.
- If the infant's IV rate was changed during the transfusion, check a glucose level every hour during the transfusion.

Donor's Blood

- Blood components should be:
 - ▶ The same as the neonate's own ABO and Rh group, or an alternative compatible ABO and Rh D group.
 - ▶ Compatible with any ABO or atypical red cell antibody present in the maternal or neonatal plasma.

Table (38-1): Criteria for ABO & Rh Compatibility of Blood Components

Guidelines for ABO-Compatible Blood Components			
ABO Group (Infant)	ABO Group (RBC's and Granulocytes)		ABO Group (FFP or Platelets)
O	O		O, A, B, or AB
A	A or O		A or AB
B	B or O		B or AB
AB	AB, A, B or O		AB
Guidelines for Rh-Compatible Blood Components			
Rh Type (Infant)	Rh Type (RBCs and Granulocytes)	Rh Type (FFP)	Rh Type (Platelets)
+ve	+ve or -ve	+ve or -ve	+ve or -ve
-ve	-ve	+ve or -ve	-ve

FFP: fresh frozen plasma, RBC: red blood cells

Component Volumes to be Transfused

- Packed red cells: 5-15 ml/kg (rate 5 ml/kg/hr); this can be adjusted depending on the severity of anemia and/or the infant's ability to tolerate increased intravascular volume
- Whole blood: 10-20 ml/kg
- Platelet concentrates: 10-20 ml/kg
- FFP: 10-20 ml/kg - cryoprecipitate: 5 ml/kg

Irradiated Blood

- Consider irradiated blood in the following populations:
 - ▶ Neonates with a birth weight <1,200 gm
 - ▶ Neonates with a known immunodeficiency syndrome
 - ▶ Neonates receiving blood from direct donor relatives

Transfusion Time

Table (38-2): The Optimal Duration of Neonatal Transfusions

Blood Product	Infusion Time	Minimum*	Maximum**
RBCs, Whole Blood	As tolerated	2 hrs	4 hrs
Platelets	As tolerated	5-15 min/unit	4 hrs
Frozen Plasma	As tolerated	30 min	4 hrs
Cryoprecipitate	As tolerated	2 min/bag	4 hr

*4 hrs are needed if the baby has symptoms of volume overload or congestive heart failure. Blood may need to be administered faster for acute blood loss or hypovolemia.

**Measured from the time the blood is taken out of the transfusion medicine refrigerator

Transfusion Reactions

Fever ($>38^{\circ}\text{C}$), tachycardia, respiratory distress, hypotension, facial flushing, pain and irritability, nausea and vomiting, blood in urine ($\geq +1$), urticaria & rash, localized or generalized, patchy or diffuse erythema of the skin

Managing a transfusion reaction

- Stop the transfusion immediately, clear the IV catheter with normal saline flush, & examine the infant immediately.
- Check and document vital signs every 15 min until the infant's condition is stable.
- Inform the blood bank physician about the reaction & send the bag, syringe & tubing to the bank. Don't send needles.
- Obtain the 1st voided urine specimen and send it for analysis.
- For future transfusions, these infants may require premedication with antihistamine.

Transfusion Complications**Table (38-3): Potential Transfusion Complications**

Complication	Cause	Prevention and/or Treatment
Sepsis	Blood contaminated with bacteria	<ul style="list-style-type: none"> • Use the blood within 4 hrs of its release from the bank. • Obtain cultures if sepsis is clinically suspected.
Hypothermia	A large volume of cold blood is transfused	<ul style="list-style-type: none"> • Warm the blood before transfusion.
Circulatory Overload	A large volume of blood is administered rapidly	<ul style="list-style-type: none"> • Avoid pushing blood fast (except for emergencies). • Consider giving a dose of furosemide if required.
Hypocalcemia	Citrate in the transfused blood may cause hypocalcemia	<ul style="list-style-type: none"> • Obtain serum calcium level. • Obtain an ECG. • Consider calcium infusion.

Intraosseous Infusion

Indications

It can be used as an **emergency vascular access** for administration of fluids and medications in life-threatening situations (e.g., shock) when other methods of vascular access have been attempted and have failed.

Contraindications

Fracture at the insertion site, cellulitis overlying the insertion site, and osteogenesis imperfecta

Equipment

Sterile towels - gloves - povidone iodine solution - sterile gauze pads (4x4) - a syringe (5 ml) - an 18-gauge disposable intraosseous needle or an 18- to 20-gauge short spinal needle with a stylet - a syringe with saline flush

Procedure

- Site: proximal tibia (preferred). Other alternative sites are the distal tibia and femur.
- Restrain the infant's lower leg and support the flexed knee by placing a towel behind the calf.
- Clean the selected area (midline on the flat surface of the anterior tibia, 1-3 cm below tibial tuberosity) with povidone-iodine solution.
- Insert the needle perpendicular to the skin at an angle 10-15° toward the foot to avoid the growth plate (**Figure 38-7**). Hold the needle with the index finger and thumb as close to the entry point as possible and, with constant pressure on the needle with the palm of the same hand. Advance the needle with a rotary motion until a lack of resistance is felt indicating that the bone marrow is reached (usually not >1 cm); proper placement is noted when the needle stands up on its own.
- Remove the stylet, attach the 5 ml-syringe to the needle and aspirate the marrow to confirm placement. If marrow is not aspirated, push with 5-10 ml NS and observe for extravasation.

- If flow is good and no extravasation is noted, connect the needle to the IV tubing, and secure the needle with gauze pads and tape.
- The needle should be removed once adequate vascular access has been established (should be optimally used for <2 hrs).

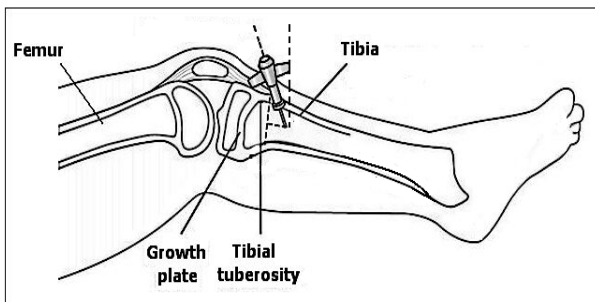


Figure (38-7): Intraosseous needle insertion

Complications

Extravasation, cellulitis, compartment syndrome, sepsis, and osteomyelitis

Decompression of Pneumothorax

Needle Aspiration

- Site: 2nd or 3rd intercostal space along midclavicular line.
- Cleanse the area with povidone-iodine solution.
- Connect a butterfly needle 21 or 23 gauge to 10-20 ml syringe with a 3-way stopcock attached.
- Palpate the 3rd rib at the midclavicular line. Insert the needle perpendicular to the chest wall and above the rib, and advance it until air is withdrawn from the syringe.
- When the syringe is full of aspirated air, close the stopcock to the chest while the syringe is emptied.
- Repeat suctioning and emptying of the aspirated air until improvement of color of the baby & SaO₂ is observed. Don't try to aspirate all air in the pleural sac.

- The needle may be removed before the chest tube is placed if the infant is relatively stable, or it may be left in place for continuous aspiration while the chest tube is being placed.

Chest Tube Placement

Equipment

Sterile towels - gauze pads (4×4) - silk suture (3-0) - needle holder - curved hemostats - scalpel (No.15 or No.11) - scissors - antiseptic solution - lidocaine (1%) - syringe (3 ml) - 25 gauge needle - sterile gloves, mask, hat and gown - a suction drainage system – a chest tube (10Fr catheter for infants weighing <2,000 gm & 12Fr for infants weighing >2,000 gm)

Procedure

- Position the infant supine with the arm at a 90° angle or with the affected side elevated 45-60° off the bed, using a towel as back support.
- Site: 2nd or 3rd intercostal space along midclavicular line. The site of insertion is different from site of entry in the intercostal space.
- Put on a sterile gown, mask, hat, and gloves. Cleanse the area of insertion with povidone-iodine then infiltrate the subcutaneous tissue with lidocaine 1% (0.125 -0.25 ml).
- Make a small incision (usually ≤0.75cm) in the skin over the rib just below the intercostal space.
- Insert a closed, curved hemostat into the incision, and spread the tissues down to the pleura grasping the end of the chest tube with the tips of the curved forceps. Apply pressure until the pleural space is entered (just above the rib. Do not use the trocar. Listen for a rush of air to indicate pleural penetration. The curve of the hemostat should be aiming anteriorly.
- Advance the tube through the opened hemostat. Direct the tube toward apex of the lung (midclavicle) and advance it, assuring that side holes are within the thorax. Observe for cloudiness, vapor, or bubbling in the chest tube to verify intrapleural location.

- The tube is inserted 2-3 cm for a preterm infant and 3-4 cm for a term infant (or measure the distance between the insertion site and the midclavicle; tie a silk suture around the tube the same distance from the tip, and then position the tube until the silk suture is just outside the skin).
- Hold the tube steady first, and then allow an assistant to connect the tube to a water-seal vacuum drainage system.
- Secure the chest tube with 3-0 silk sutures and silk tape. Close the skin opening with sutures if necessary.
- Obtain a chest x-ray film to verify placement.

Removal of the chest tube

Prior to removal, the chest tube should be clamped for 6 hrs. If there is no re-accumulation of air, the chest tube can be removed.

Complications

Infection, bleeding, nerve damage, lung trauma, diaphragmatic paralysis, subcutaneous emphysema, and malpositioning

Appendices

Common NICU Drugs

Acyclovir	
Dosage: 20 mg/kg/dose PO - IV (infuse over 60 min)	
Localized HSV infections	PMA <34 wks or renal impairment or hepatic failure: IV q12 hrs for 14 days
	PMA \geq 34 wks: IV q8 hrs for 14 days
Disseminated or CNS infections	PMA <34 wks or renal impairment or hepatic failure: IV q12 hrs for 21days
	PMA \geq 34 wks: IV q8 hrs for 21days
Varicella Zoster infections	PO q6 hrs (initiated within the first 24 hrs of disease onset) for 5 days
Precautions	<ul style="list-style-type: none"> - Lengthen dosing interval with renal failure - Monitor renal function - Infusion solution concentration <7 mg/ml
Albumin	
Dosage	0.5-1 gm/kg IV (or 10-20 ml/kg of 5% IV bolus) repeated as necessary; maximum 6 gm/kg/day
Precautions	<ul style="list-style-type: none"> - Contraindicated in CHF - Monitor BP

Appendix 1: Common NICU Drugs

<i>Amikacin Sulfate</i>	
Dosage: IM - IV (infuse over 30 min)	
PMA \leq 29 wks (or significant asphyxia, PDA, indomethacin therapy, \downarrow renal function)	PNA 0-7 days: 18 mg/kg/dose q48 hrs
	PNA 8-28 days: 15 mg/kg/dose q36 hrs
	PNA \geq 29 days: 15 mg/kg/dose q24 hrs
PMA 30-34 wks	PNA 0-7 days: 18 mg/kg/dose q36 hrs
	PNA $>$ 7 days: 15 mg/kg/dose q24 hrs
PMA $>$ 35 wks	All neonates: 15 mg/kg/dose q24 hrs
Precautions	<ul style="list-style-type: none"> - Monitor serum level when treating $>$48 hrs (trough 2-5 μg/ml & peak 20-30 μg/ml) - Monitor renal function - For IV use, dilute to 5 mg/ml concentration
<i>Aminophylline</i>	
Dosage: PO - IV	
Loading	5-6 mg/kg/dose IV (over $>$ 20 minutes) or PO
Maintenance	1.5-3 mg/kg/dose PO, IV slow push ($>$ 5 min) q8-12 hrs (start 8-12 hrs after the loading dose)
Changing IV to PO	\uparrow dose by 20%
Precautions	<ul style="list-style-type: none"> - Monitor serum trough levels before the 5th dose (levels in apnea 7-12 μg/ml) - Monitor HR, blood glucose and feeding intolerances and agitation; if HR$>$180 /min, withhold next dose - Dilute 1 ml + 4 ml NS or D5W \rightarrow 5 mg/ml

Amphotericin B	
Dosage	
Initial	0.25-0.50 mg/kg IV infusion over 2-6 hrs, diluted in D5W to 0.1mg/ml concentration
Maintenance	↑ daily dose by 0.125-0.25 mg/kg/day IV infusion over 2-6 hrs, until a maximum daily or alternate-day dosage of 0.75-1.5 mg/kg has been attained (a total dosage of 30-35 mg/kg should be given over ≥6 wks)
Liposomal amphotericin B	5 mg/kg/dose q24 hrs IV infusion over >2 hrs
Precautions	<ul style="list-style-type: none"> - Do not flush IV or mix with NS - Avoid additional nephrotoxic drugs - Monitor BUN, serum creatinine, electrolytes and AST (daily or every other day until dose is stabilized, then weekly) & CBC weekly - Modify dosage if serum creatinine increases >0.4 mg/dl during therapy and discontinue if BUN >40 mg/dl, serum creatinine >3mg/dl or if liver function tests are abnormal
Ampicillin	
Dosage: IM - IV (infuse over >15 min)	
Meningitis	PNA 0-7 days: 100-200 mg/kg/day divided q12 hrs
	PNA >7 days: 200-300 mg/kg/day divided q8 hrs (maximum: 400 mg/kg/day)
Other indications	PNA 0-7 days: 100 mg/kg/day divided q12 hrs
	PNA >7 days: 100 mg/kg/day divided q8 hrs
Precautions	<ul style="list-style-type: none"> - Maximum concentration for IV 100 mg/ml - Adjust dose in renal impairment

Appendix 1: Common NICU Drugs

<i>Ampicillin/Sulbactam</i>	
Dosage: IM - IV	
Meningitis	PNA 0-7 days: 100-200 mg/kg/day divided q12 hrs
	PNA >7 days: 200-300 mg/kg/day divided q6-8 hrs
Other infections	PNA 0-7 days: 100 mg/kg/day divided q12 hrs
	PNA >7 days: 100 mg/kg/day divided q6-8 hrs
Precautions	See ampicillin
<i>Calcium Gluconate 10%</i>	
Dosage: IV infusion	
Acute	100-200 mg/kg/dose (1-2 ml/kg/dose) IV over 10-30 min
Maintenance	200-800 mg/kg/day (2-8 ml/kg/day) continuous IV infusion
Exchange transfusion	100 mg/100 ml <u>or</u> 1 ml/100 ml citrated exchange blood
Precautions	<ul style="list-style-type: none"> - Monitor HR, and stop if HR <100/min - Observe IV infusion site for extravasation
<i>Captopril</i>	
Dosage	<ul style="list-style-type: none"> - Initial: 0.01-0.05 mg/kg/dose PO q8-12hrs (adjust dose and interval; based on response) - Maximum recommended dose 0.5 mg/kg/ dose PO q6-24 hrs
Precautions	<ul style="list-style-type: none"> - Use a low initial dose - Administer 1 hr before, or 2 hrs after feeding - Reduce the dose with renal impairment - Contraindicated in bilateral renal artery stenosis - Monitor BP (particularly after the 1st dose), BUN, serum creatinine, urine dipstick for protein, CBC, and serum K⁺

Cefepime	
Dosage : IM - IV (infuse over 30 min)	
Term and preterm infants	PNA \leq 14 days: 30 mg/kg/dose q12 hrs
	PNA >14 days: 50 mg/kg/dose q12 hrs
Meningitis & severe infections	Doses administered q8 hrs
Precautions	Maximum concentration for IV (160 mg/ml) & for IM administration (280 mg/ml)
Cefotaxime Sodium	
Dosage : IM - IV (infuse over 30 min)	
Meningitis	50 mg/kg/dose q6 hrs
Gonococcal conjunctivitis	25 mg/kg/dose q12 hrs
Other infections	PNA 0-7 days: 50 mg/kg/dose q12 hrs
	PNA >7 days: 50 mg/kg/dose q8 hrs
Precautions	<ul style="list-style-type: none"> - Adjust dose for renal impairment - For IV administration, reconstitute to 100 mg/ml concentration
Ceftazidime	
Dosage: 30 mg/kg/dose IM - IV (infuse over 30 min)	
PMA \leq 29 wks	PNA 0-28 days: q12 hrs
	PNA >28 days: q8 hrs
PMA 30-36 wks	PNA 0-14 days: q12 hrs
	PNA >14 days: q8 hrs
PMA 37-44 wks	PNA 0-7 days: q12 hrs
	PNA >7 days: q8 hrs
Precautions	<ul style="list-style-type: none"> - Modify dosage for renal impairment - For IV use, reconstitute to 50 mg/ml

Appendix 1: Common NICU Drugs

<i>Ceftriaxone Sodium</i>	
Dosage: IV - IM	
Meningitis	Loading: 100 mg/kg q24 hrs
	Maintenance: 80 mg/kg q24 hrs
Other indications	50 mg/kg q24 hrs
Precautions	<ul style="list-style-type: none"> - Do not use in hepatobiliary, or pancreatic disease - Use with caution in infants with hyperbilirubinemia - Monitor CBC, electrolytes and renal & liver functions - Should not be reconstituted or mixed with calcium-containing products - For IV use: reconstitute to 40 mg/ml
<i>Clindamycin</i>	
Dosage: 5 mg/kg/dose IV (infuse over >30 min)	
<1,200 gm	PNA 0-28 days: q12 hrs
1,200-2,000 gm	PNA 0-7 days: q12 hrs
	PNA >7 days: q8 hrs
>2,000 gm	PNA 0-7 days: q8 hrs
	PNA >7 days: q6 hrs
Precautions	<ul style="list-style-type: none"> - Do not use to treat meningitis - Contraindicated in hepatic impairment - Infusion concentration: 10 mg/ml (maximum 18 mg/ml)

Dexamethasone	
Dosage	
BPD	0.2-0.3 mg/kg/day divided q12 hrs for 48 hrs, then halve the dose q48 hrs for 7-10 days
Extubation/ airway edema	0.25 mg/kg/dose q12 hrs (begin 12 hrs before extubation & continue for 2-4 doses afterwards)
Precautions	<ul style="list-style-type: none"> - Monitor BP - Assess Hb, serum K⁺ & serum glucose levels - Evaluate for glycosuria & occult blood loss
Diazepam	
Dosage	
Status epilepticus	- 0.1-0.3 mg/kg/dose IV q15-30 min for 2-3 doses (maximum dose 2-5 mg)
Continuous refractory seizures	<ul style="list-style-type: none"> - 0.1-0.3 mg/kg/dose IV bolus, then - 0.3 mg/kg/hr continuous IV infusion (dilute with NS → 0.1 mg/ml concentration)
Precautions	<ul style="list-style-type: none"> - Drowsiness, ataxia, rash, vasodilation, respiratory arrest, and hypotension - Prepare for possible respiratory depression
Digoxin	
Dosage: IV (infuse over 10 min) - PO	
Loading: IV - divided into 3 doses over 24 hrs	PMA ≤ 29 wks: 0.15 mg/kg divided q8 hrs
	PMA 30-36 wks: 0.2 mg/kg divided q8 hrs
	PMA >36 wks: 0.3 mg/kg divided q8 hrs
Maintenance IV	PMA <29 wks: 0.04 mg/kg/dose q24 hrs
	PMA 30-36 wks: 0.05 mg/kg/dose q24 hrs
	PMA >36 wks: 0.04 mg/kg/dose q12 hrs
PO - loading & maintenance	25% greater than IV doses

Appendix 1: Common NICU Drugs

Precautions	<ul style="list-style-type: none"> - Contraindicated in 2nd - and 3rd -degree block, idiopathic hypertrophic subaortic stenosis & ventricular arrhythmias - Reduce dose for renal impairment - Monitor HR/rhythm, serum K⁺, calcium, magnesium & signs of toxicity (especially in infants receiving diuretics & amphotericin B) - For IV use, dilute into 4-folds or greater volume of a compatible solution; use immediately
Dobutamine Hydrochloride	
Dosage	2.5-25 µg/kg/min - continuous IV infusion (begin at a low dose & titrate by monitoring effects)
Precautions	<ul style="list-style-type: none"> - Contraindicated in idiopathic subaortic stenosis, and atrial fibrillation - Correct hypovolemia before use - Do not administer via UAC - Monitor HR & BP
Dopamine Hydrochloride	
Dosage: continuous IV infusion	
Low dose	2-5 µg/kg/min (renal dose)
Medium dose	5-15 µg/kg/min (cardiotonic dose)
High dose	>20 µg/kg/min (pressor dose)
Precautions	<ul style="list-style-type: none"> - Use with caution in infant receiving phenytoin IV - Do not administer via UAC - Monitor HR, BP, urine output & peripheral perfusion

N.B.: Dopamine (or dobutamine) must be given in a separate IV line.

N.B.: Suggested administration

$$\frac{6 \times \text{body weight} \times \text{desired dose } (\mu\text{g/kg/min})}{\text{fluid rate (ml/hr)}} = \frac{\# \text{ mg Desired}}{\text{Dopamine/100 ml solution}}$$

<i>Epinephrine Hydrochloride</i>	
Dosage	
Cardiac arrest or severe bradycardia	IV push: 0.1-0.3 ml/kg/dose (1:10,000 concentration) may repeat q3-5 min (total 3 doses), if HR remains <60/min
	ETT: 0.3-1.0 ml/kg/dose (1:10,000 concentration)
Continuous IV infusion	Start at 0.1 µg/kg/min, adjust dose to desired response (maximum 1 µg/kg/min); maximum IV concentration (1 mg/50 ml)
Precautions	Monitor HR & BP continuously
<i>Erythromycin</i>	
Dosage: IV (infuse over > 60 min) – PO	
Systemic infections 10 mg/kg/dose	PNA ≤7 days: q12 hrs
	PNA >7 days, <1200 gm: q12 hrs
	PNA >7 days, ≥1200 gm: q8 hrs
Feeding intolerance	10 mg/kg/dose PO q6 hrs for 2 days, then 4 mg/kg/ dose PO q6 hrs for 5 days, 30 min before feedings
Ophthalmic (prophylaxis)	Instill 0.5-1 cm in each eye once
Acute eye infection	Instill 0.5-1 cm in each eye q6 hrs
Precautions	<ul style="list-style-type: none"> - Parenteral forms are painful - Monitor liver functions & CBC

Appendix 1: Common NICU Drugs

<i>Ferrous Sulfate</i>		
Dosage: PO (preferably diluted in formula)		
Iron deficiency anemia	6 mg/kg/day in divided 4 divided doses	
Prophylaxis	<ul style="list-style-type: none">- Growing premature infants: 2 mg/kg/day- Infants <1,000 gm: 4mg/kg/day- Start therapy no later than 2 months of age	
Supplementation with erythropoietin	6 mg/kg/day	
Precautions	<ul style="list-style-type: none">- Monitor Hb & reticulocytic count- Monitor for constipation	
<i>Fluconazole</i>		
Dosage: PO, IV infusion (by syringe pump over 60 min)		
Systemic infections, including meningitis	Loading	12 mg/kg
	Maintenance (6 mg/kg /dose)	PMA ≤36 wks, PNA 0-14 days: q48 hrs
		PMA ≤36 wks, PNA >14 days: q24 hrs
		PMA >36 wks, PNA 0-7 days: q48 hrs
		PMA >36 wks, PNA >7 days: q24 hrs
Thrush	<ul style="list-style-type: none">- Loading: 6 mg/kg on day 1- Then: 3 mg/kg/dose q24 hrs PO	
Prophylaxis	<ul style="list-style-type: none">- Loading: 3 mg/kg/dose, once daily 3 times weekly for 1st 2 wks- Then every other day for total of 4-6 wks (longer duration for infants < 1,000 gm)	
Precautions	<ul style="list-style-type: none">- Adjust dosage for impaired renal function- Monitor renal & liver function tests	

<i>Furosemide</i>	
Dosage: PO, IM, and IV slow push	
Initial dose	1 mg/kg/dose (maximum of 2 mg/kg/dose IV or 6 mg/kg/dose PO)
Initial intervals	<ul style="list-style-type: none"> - Premature infant: q24 hrs - Full-term infant: q12 hrs - Full term infant older than 1 month: q6-8 hrs - Consider alternate-day therapy for long-term use
Precautions	<ul style="list-style-type: none"> - Monitor daily weight change, urine output, serum phosphate & serum electrolytes - Monitor serum K⁺ in infants receiving digoxin
<i>Gentamicin Sulfate</i>	
Dosage: IM - IV (infuse over 30 min)	
PMA ≤ 29 wks (or significant asphyxia, PDA, treatment with indomethacin or impaired renal function)	PNA 0-7 days: 5 mg/kg/dose q48 hrs
	PNA 8-28 days: 4 mg/kg/dose q36 hrs
	PNA ≥29 days: 4 mg/kg/dose q24 hrs
PMA 30-34 wks	PNA 0-7 days: 4.5 mg/kg/dose q36 hrs
	PNA ≥8 days: 4 mg/kg/dose q24 hrs
PMA >35 wks	4 mg/kg/dose q24 hrs
Precautions	<ul style="list-style-type: none"> - Measure serum level when treating >48 hrs (desirable levels; trough 0.5-1 µg/ml & peak 6-15 µg/ml). - Modify dosage for impaired renal function - Addition of nephrotoxic and/or ototoxic drugs may increase adverse effects - Monitor renal function

Appendix 1: Common NICU Drugs

Heparin Sodium	
Dosage	
Thrombosis	<ul style="list-style-type: none"> - Loading: 75 units/kg as IV bolus - Maintenance: 28 units/kg/hr as continuous infusion 4 hrs after loading therapy, measure APTT; adjust to achieve APTT 60-85 seconds - Therapy should be limited to 10-14 days
Patency of vascular catheter	0.5-1 unit/ml of IV fluid
Precautions	<ul style="list-style-type: none"> - Monitor platelet count every 2-3 days - Monitor for bleeding & thrombosis
Antidote	Protamine sulfate, 1 mg for each 100 units of heparin given in the preceding 3-4 hrs up to a maximum dose of 50 mg
Hydrocortisone	
Dosage	
Acute adrenal insufficiency	50-100 mg/m ² (≈25 mg) given IV bolus immediately, followed by 100 mg/m ² /24 hrs by continuous drip or divided q6 hrs
Congenital adrenal hyperplasia	Acute crisis: as acute adrenal insufficiency Once clinical condition improves, taper the dose by 1/3 per day to 10-15 mg/m ² /day PO in 3 doses
Refractory hypoglycemia	5 mg/kg/dose IV q12 hrs
Refractory hypotension in critically ill preterm infants	1 mg/kg IV q8-12 hrs for 2-3 days
Precautions	Abrupt withdrawal following long-term therapy or during periods of stress → acute adrenal insufficiency

Ibuprofen	
Dosage	10 mg/kg IV one dose, then 5 mg/kg IV at 24 and 48 hrs after initial dose
Precautions	<ul style="list-style-type: none"> - Avoid use with steroids - Contraindicated in preterm infants with infection, active bleeding, thrombocytopenia or coagulation defects & significant renal dysfunction - Use caution in infants with decreased hepatic or renal functions, dehydration, hypertension, GI bleeding, or those receiving anticoagulants - Monitor BUN, serum creatinine, CBC - Monitor urine output - Assess ductal closure & signs of bleeding
Imipenem/Cilastatin	
Dosage: 20 mg/kg/dose IV infusion over 30 min	
<1,200 gm	PNA: 0-28 days: q18-24 hrs
	PNA: >29 days: q12 hrs
1,200-2,000 gm	q12 hrs
>2,000 gm	PNA: 0-7 days q12 hrs
	PNA: >7 days q8 hrs
Precautions	<ul style="list-style-type: none"> - Maximum concentration 5mg/ml - Periodically monitor CBC & hepatic enzymes - Assess IV site for signs of phlebitis
Immune Globulin, Intravenous (IVIG)	
Dosage	500-750 mg/kg/dose q24 hrs IV infusion over 2-6 hrs for 1-2 doses
Precautions	<ul style="list-style-type: none"> - Delay immunizations with live virus vaccines until 3-11 months after administration - Monitor HR & BP

Appendix 1: Common NICU Drugs

Indomethacin		
Dosage: IV infusion over >30 min, all doses given in 12-24 hrs intervals (three doses/course, maximum 2 courses)		
	1 st dose	2 nd and 3 rd doses
PNA ≤48 hrs	0.2 mg/kg/dose	0.1 mg/kg/dose
PNA 2-7 days	0.2 mg/kg/dose	0.2 mg/kg/dose
PNA >7 days	0.2 mg/kg/dose	0.25 mg/kg/dose
Precautions	<ul style="list-style-type: none">- Contraindicated in active bleeding, significant thrombocytopenia or coagulation defects, NEC & significant renal dysfunction- Use with caution in neonates with cardiac dysfunction & hypertension- Monitor urine output, serum electrolytes, BUN, serum creatinine, platelet counts & PDA- Assess stools & gastric aspirate for GI bleeding, prolonged bleeding in puncture sites- Consider withholding enteral feedings during therapy	
Magnesium Sulfate (MgSO ₄)		
Dosage: IM - IV infusion over 30 min - Magnesium sulfate (50% solution) contains 500 mg or 4 mEq/ml		
Acute hypo-magnesemia	<ul style="list-style-type: none">- 0.2-0.4 mEq/kg (0.05-0.1 ml/kg)- Repeated doses may be required q6-12 hrs until serum level is normal or symptoms resolve- Concomitant oral magnesium can be started if oral feeds are tolerated (0.2 ml/kg/day).- In specific magnesium malabsorption, daily oral doses of 1 ml/kg/day may be required	
Maintenance	<ul style="list-style-type: none">- 0.25-0.5 mEq/kg/24 hrs IV (added to IV fluids)	
Precautions	<ul style="list-style-type: none">- Contraindicated in renal failure- Monitor BP, serum Mg, Ca & phosphate levels	

Meropenem		
Dosage: IV infusion over 30 min		
Sepsis	20 mg/kg/dose q12 hrs	
Meningitis & Pseudomonal infection	40 mg/kg /dose q8 hrs	
Precautions	<ul style="list-style-type: none">- Maximum concentration (50 mg/ml)- Periodically monitor CBC & hepatic enzymes- Assess IV site for signs of inflammation	
Metronidazole		
Dosage: PO - IV (infuse over 60 min)		
PNA <7 days	<1,200 gm	7.5 mg/kg/dose q48 hrs
	1,200-2,000 gm	7.5 mg/kg/dose q24 hrs
	≥2,000 gm	7.5mg/kg/dose q12 hrs
PNA ≥7 days	<1,200 gm	7.5 mg/kg/dose q24 hrs
	1,200-2,000 gm	7.5mg/kg/dose q12 hrs
	≥2,000 gm	15 mg/kg/24 hr q12 hrs
Precautions	Drug metabolites may cause brownish discoloration of the urine	
Midazolam Hydrochloride		
Dosage		
Intermittent IV (over at least 5 min)	0.05-0.15 mg/kg/dose q2-4 hrs, as needed	
Continuous infusion	0.01-0.06 mg/kg/hr	
Precautions	<ul style="list-style-type: none">- Caution if used with fentanyl concurrently- Monitor RR, HR & BP	

Appendix 1: Common NICU Drugs

<i>Naloxone Hydrochloride</i>		
Dosage	0.1mg/kg/dose, IV push over 30 seconds (can be administered via SC/IM/ET routes); can be repeated q3-5 min	
Precautions	Monitor for reappearance of respiratory depression and the need for repeated doses	
<i>Oxacillin Sodium</i>		
Dosage: IV (infuse over >10 min)		
Bacteremia: 25mg/kg/dose Meningitis and sever systemic infection: 50 mg/kg/dose	PNA ≤7 days, <2,000 gm:	q12 hrs
	PNA ≤7 days, >2,000 gm:	q8 hrs
	PNA >7 days, <2,000 gm:	q8 hrs
	PNA >7 days, >2,000 gm:	q6 hrs
Precautions	<ul style="list-style-type: none">- Maximal concentration for IV (100 mg/ml)- Monitor CBC, BUN, creatinine & urine for hematuria and/or proteinuria	
<i>Penicillin G Preparations</i>		
Dosage: IM - IV (infuse over >30 min)		
Bacteremia: 25,000-50,000 units/kg/dose Meningitis: 75,000-100,000 units/kg/dose	PMA ≤36 wks, PNA 0-14 days	q12 hrs
	PMA ≤36 wks, PNA >14 days	q8 hrs
	PMA >36 wks, PNA 0-7 days	q12 hrs
	PMA >36 wks, PNA >7 days	q12 hrs
Precautions	<ul style="list-style-type: none">- Rapid IV push of potassium penicillin G may → cardiac arrhythmias & arrest- Monitor serum K⁺ & Na⁺, when using high dose and in infant with renal failure- Assess weekly CBC, BUN & serum creatinine- Final concentration for IV (50,000 units/ml)	

Phenobarbital		
Dosage		
Seizures	Loading	20 mg/kg/dose, IV infusion over >15 min (rate <1mg/kg/min), additional doses of 5 mg/kg q5 min, until cessation of seizures or a total dose of 40 mg/kg
	Maintenance	3-5 mg/kg/day, divided q12 hrs, IV (preferred for seriously ill infant), IM/PO (24 hrs after loading dose)
Hyper-bilirubinemia	4-5 mg/kg/day, IV/IM/PO for 4-5 days	
Precautions	<ul style="list-style-type: none">- Therapeutic trough serum level 15-40 µg/ml- Abrupt discontinuation in infant with seizure → status seizures- Monitor respiration during administration- Assess IV site for extravasations	
Phenytoin		
Dosage: IV (infuse over 30-60 min) - PO		
Status epilepticus	Loading	15-20 mg/kg/day IV over at least 30 min (dilute to 5 mg/ml with NS and start infusion immediately after preparation)
	Maintenance	5-8 mg/kg/day IV slow push or PO divided q8-12 hrs
Anti-arrhythmia (digitalis induced)	Loading	1.25 mg/kg IV q5 min up to a total of 15 mg/kg
	Maintenance	5-8 mg/kg/ day, divided q8-12 hrs
Precautions	<ul style="list-style-type: none">- Rapid IV administration → hypotension, cardiovascular collapse & CNS depression- Infusion rate should not >0.5 mg/kg/min	

Appendix 1: Common NICU Drugs

	<ul style="list-style-type: none"> - Check for multiple drug interactions - Obtain trough level 48 hrs after IV loading dose (therapeutic level 18-15 µg/ml) - Monitor for bradycardia, arrhythmia & hypotension during infusion - Incompatible with D5W & D10W
Piperacillin/Tazobactam	
Dosage: 50-100 mg/kg/dose - IV (infuse over 30 min)	
PMA ≤29 wks	PNA 0-28 days: q12 hrs
	PNA >28 days: q8 hrs
PMA 30-36 wks	PNA 0-14 days: q12 hrs
	PNA >14 days: q8 hrs
PMA ≥37 wks	PNA 0-7 days: q12 hrs
	PNA >7 days: q8 hrs
Precautions	<ul style="list-style-type: none"> - Eosinophilia, hyperbilirubinemia, ↑ALT, AST, BUN & serum creatinine - Observe IV sites for signs of extravasation - Compatible solutions: D5W, D10W & NS
Propranolol	
Dosage	
Starting oral dose	0.25-2 mg/kg/dose q6 hrs, increase as needed (maximum 3.5 mg/kg/dose q6 hrs)
Starting IV dose	0.01 mg/kg q6 hrs over 10 min, increase as needed (maximum 0.15 mg/kg/dose q6 hrs)
Precautions	<ul style="list-style-type: none"> - Use caution in renal or hepatic failure - Contraindicated in obstructive pulmonary disease, asthma, heart failure, shock, 2nd-or -3rd degree heart block & hypoglycemia

Prostaglandin E₁	
Dosage	
Initial	<ul style="list-style-type: none"> - 0.05-0.1 µg/kg/min, continuous IV infusion - Titrate to infant's response-oxygenation versus adverse effects
Maintenance	- May be as low as 0.01 µg/kg/min
Precautions	<ul style="list-style-type: none"> - Monitor for apnea (consider aminophylline), bradycardia & severe hypotension; be ready for intubation & resuscitation - Contraindicated in infants with RDS, PPHN - Dilute before administration to <20 µg/ml concentration
Pyridoxine (Vitamin B6)	
Dosage	
Pyridoxine dependent seizures	50-100 mg IV or IM over 1 min, follow with a 30 min observation period, if a response, continue with the maintenance dose
Maintenance	50-100 mg q24 hrs PO
Precautions	Risk of respiratory depression; MV may be needed
Ranitidine	
Dosage	
PO	2 mg/kg/dose q 8hrs
IV	0.5mg/kg/dose q6 hrs, infuse over 15 min (Maximum concentration: 2.5 mg/ml)
IV infusion	0.0625 mg/kg/hr
Precautions	<ul style="list-style-type: none"> - Monitor gastric pH - Use with caution in infants with liver & renal impairment

Appendix 1: Common NICU Drugs

<i>Sodium Bicarbonate (8.4% concentration)</i>	
Dosage	
Cardiac arrest	<ul style="list-style-type: none"> - 1-2 mEq/kg/min- IV slow push over 2 min - May be repeated with 0.5 mEq/kg q10 min, or as indicated by the acid-base status
Metabolic acidosis	$\text{HCO}_3^- \text{ dose (mEq)} = 0.3 \times \text{Base deficit (mEq/L)} \times \text{Body weight (kg)}$ - infuse IV over >30 min on syringe pump (administer $\frac{1}{2}$ of calculated dose, and then assess the need for remainder).
Renal tubular acidosis	<ul style="list-style-type: none"> - Distal: 2-3 mEq/kg/day - PO or IV - Proximal: 5-10 mEq/kg/day - PO or IV
Precautions	<ul style="list-style-type: none"> - Dilute 1:1 with sterile water or D5W - Do not infuse with calcium or phosphate containing solutions - Monitor acid base, ventilation status & serum electrolytes
<i>Surfactants</i>	
Dosage	
<u>Prophylaxis:</u> birth weight <1,250 gm <u>Rescue therapy:</u> moderate to severe RDS (MV & FiO_2 >40%) Administer intra-tracheally by instillation into 5Fr end-hole catheter inserted into the infant's ETT with the tip of the catheter protruding just beyond the end of ETT and above the carina	
Beractant	4 ml/kg/dose divided into 4 aliquots, with up to 3 additional doses (4 total) q6 hrs, as needed
Precautions	<ul style="list-style-type: none"> - Assess ETT patency, correct anatomic location & suction ETT before administration - Monitor SaO_2, HR during administration - Delay suctioning post-administration (>1 hr) - Monitor arterial blood gases - Discard vials with residual drugs

Vancomycin Hydrochloride	
Dosage: meningitis 15 mg/kg/dose, bacteremia 10 mg/kg/dose IV (infuse over 60 min)	
PMA \leq 29 wks	PNA 0-14 days: q18 hrs
	PNA >14days: q12 hrs
PMA 30-36 wks	PNA 0-14 days: q12 hrs
	PNA >14days: q8 hrs
PMA >36 wks	PNA 0-7 days: q12 hrs
	PNA >7 days: q8 hrs
Oral	20-40 mg/kg/day divided q6 hrs for 5-7 days
Precautions	<ul style="list-style-type: none"> - Ototoxicity (enhanced by aminoglycoside therapy) & nephrotoxicity - Too-rapid infusion \rightarrow rash, chills & fever (red-man syndrome –anaphylactic reaction) - Give caution in infants with renal impairment or those receiving nephrotoxic or ototoxic drugs - Monitor trough level (desired 5-15 μg/ml) - Final concentration for infusion (5mg/ml)
Vitamin K₁	
Dosage	
Hemorrhagic disease of the newborn	
Prophylaxis	<1,500 gm: 0.5 mg IM, SC
	\geq 1,500 gm: 1mg IM, SC
Treatment	1-2 mg as a single dose slow IV push
Deficiency states	1 mg/day PO, IM, or slow IV push
Precautions	<ul style="list-style-type: none"> - Allow a minimum of 2-4 hrs to detect a measurable improvement - IV administration is restricted to emergency use & should not exceed 1 mg/min

Biophysical Profile

BFP is used to assess fetal well-being. NST is performed along with an ultrasound examination.

Table (A2-1): Biophysical Profile Scoring

Variable	Normal score (score=2)	Abnormal (score=0)
Fetal Breathing Movements	At least 1 episode of FBM of at least 30 seconds duration in 30 min observation	Absent FBM or episode < 30 seconds in 30 min
Gross Body Movement	At least 3 discrete body/limb movements in 30 min	2 or less
Fetal Tone	At least 1 episode of active extension with return to flexion of fetal limbs or trunk	Either a slow extension with return to partial flexion or movement of limb in full extension or absent fetal movement
Reactive FHR	At least 2 episodes of FHR acceleration >15 beats/min and at least 15 seconds duration, associated with fetal movement in 30 min	Less than 2 episode of acceleration of FHR or acceleration of <15 beats/min in 30 min
Amniotic Fluid Volume	At least 1 pocket of amniotic fluid that measures at least 2 cm in 2 perpendicular planes	Either no amniotic fluid pockets or a pocket <2 cm in 2 perpendicular planes

- Interpretation:
 - ▶ Score 8-10: Reassuring, repeated at weekly interval
 - ▶ Score 4-6: Less reassuring, repeated later the same day
 - ▶ Score 0-2: High perinatal mortality, prompt delivery

The Apgar Scoring System

The Apgar score is a tool that can be used objectively to define the state of an infant at given times after birth, traditionally at 1 minute and 5 minutes.

Table (A3-1): The Apgar Score in Newborn

Sign	0	1	2
Heart Rate	Absent	<100 beats/min	>100 beats/min
Respiratory Effort	Absent	Slow (irregular)	Good crying
Muscle Tone	Limp	Some flexion of extremities	Active motion
Reflex Irritability	No response	Grimace	Cough or sneeze
Color	Blue	Pale pink body Blue extremities	All pink

After 1 minute: to evaluate presence of intrapartum asphyxia.

After 5 minutes: to assess adequacy of resuscitation.

After 10 minutes: to assess prognosis.

When the 5-minute score is <7, additional scores should be assigned every 5 minutes for up to 20 minutes.

New Ballard Score

- Time: it is best performed at <12 hrs of age if the infant is <26 wks' gestation. If the infant is >26 wks' gestation, there is no optimal age of examination up to 96 hrs.
- Examination is performed twice by 2 different examiners.
- Examination consists of 2 parts; neuromuscular maturity and physical maturity.
- Assess the infant's neuromuscular maturity and place an (X) in the box on the form which best describes the infant. When a 2nd examination is performed, place a (0) in the appropriate box.
- Assess the infant's physical maturity and place an (X) in the box on the form which best describes the infant. When a 2nd examination is performed, place a (0) in the appropriate box.
- Add up the scores received for each of the checked boxes and record the total scores on the worksheet.
- Maturity rating: compare the total score obtained from the assessment in the score column to the estimated GA in the weeks' column.

N.B.: If the infant was compromised during labor and delivery, neurological maturity may not be accurately assessed at this time and should be repeated after 24 hrs of age. If the neurological assessment is not performed, the GA estimate can be based upon a doubling of the physical assessment score

- Plot the infant's weight, length, and head circumference against the estimated GA to determine whether the infant is SGA, AGA, or LGA (using intrauterine growth chart "Lubchenco charts").

Appendix 4: New Ballard Score

Neuromuscular maturity signs	Score							Score	Weeks
	-1	0	1	2	3	4	5	-10	20
Posture								-5	22
Square window (wrist)								0	24
Arm recoil								5	26
Popliteal angle								10	28
Scarf sign								15	30
Heel to ear								20	32
								25	34
								30	36
								35	38
								40	40
								45	42
								50	44

Physical maturity signs	-1	0	1	2	3	4	5
Skin	Sticky, friable, transparent	Gelatinous, red, translucent	Smooth, pink, visible veins	Superficial peeling and/or rash, few veins	Cracking, pale areas, rare veins	Parchment, deep cracking, no vessels	Leathery, cracked, wrinkled
lanugo	None	Sparse	Abundant	Thinning	Bald areas	Mostly bald	
Plantar surface	Heel-toe 40-50 mm: -1 < 40 mm: -2	> 50 mm No crease	Faint red marks	Anterior transverse crease only	Creases anterior 2/3	Crease over entire sole	
Breast	Imperceptible	Barely Perceptible	Flat areola, no bud	Stippled areola, 1-2 mm bud	Raised areola, 3-4 mm bud	Full areola, 5-10 mm bud	
Eye/Ear	Lids fused loosely: -1 Tightly: -2	Lids open Pinna flat, stays folded	Slightly curved pinna; soft slow recoil	Well-curved pinna, soft but ready recoil	Formed and firm, instant recoil	Thick cartilage, ear stiff	
Genitals (male)	Scrotum flat, smooth	Scrotum empty, faint rugae	Testes in upper canal, Rare rugae	Testes descending, few rugae	Testes down, good rugae	Testes pendulous, deep rugae	
Genitals (female)	Clitoris prominent, labia flat	Prominent clitoris, labia minora	Prominent clitoris, enlarging minora	Majora and minora equally prominent	Majora large, minora small	Majora cover clitoris and minora	

Figure (A4-1): Neuromuscular and physical maturity (New Ballard Score)

Ballard JL Khoury JC, Wedig K, et al. New Ballard Score expanded to include extremely premature infants. J Pediatr 1991; 119: 417.

Appendix 4: New Ballard Score

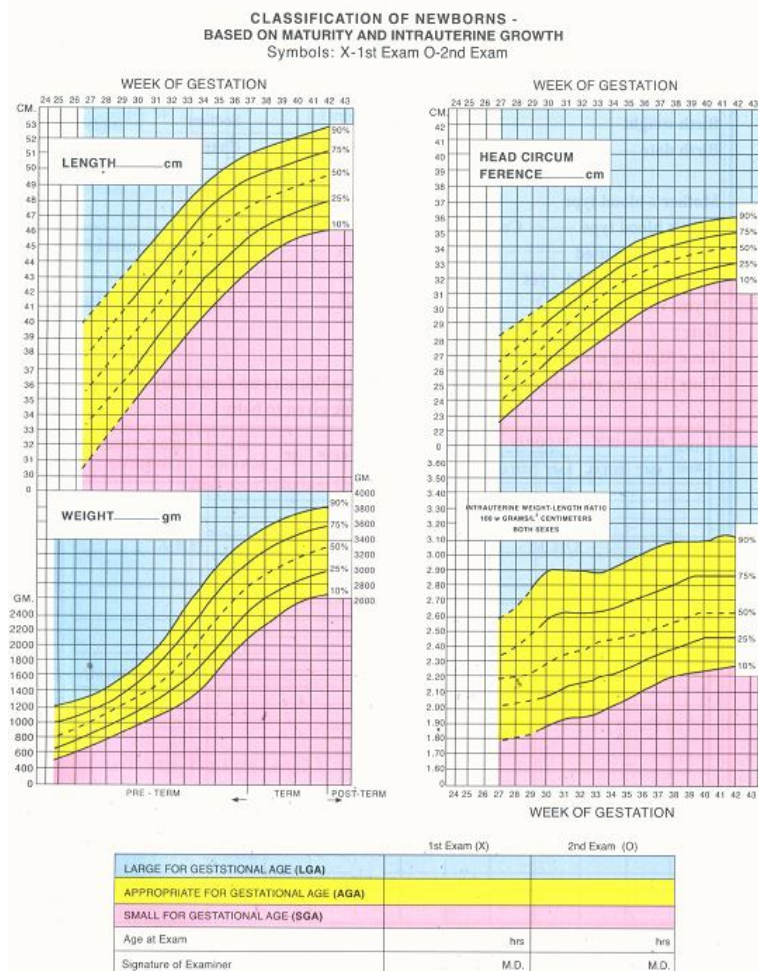


Figure (A4-2): Classification of newborns by intrauterine growth and GA

Lubchenco LO, Hansman C, Boyd E. Intrauterine growth in length and head circumference as estimated from live births at gestational ages from 26 to 42 weeks. *Pediatrics* 1966; 37:403.

Extrauterine Growth Chart

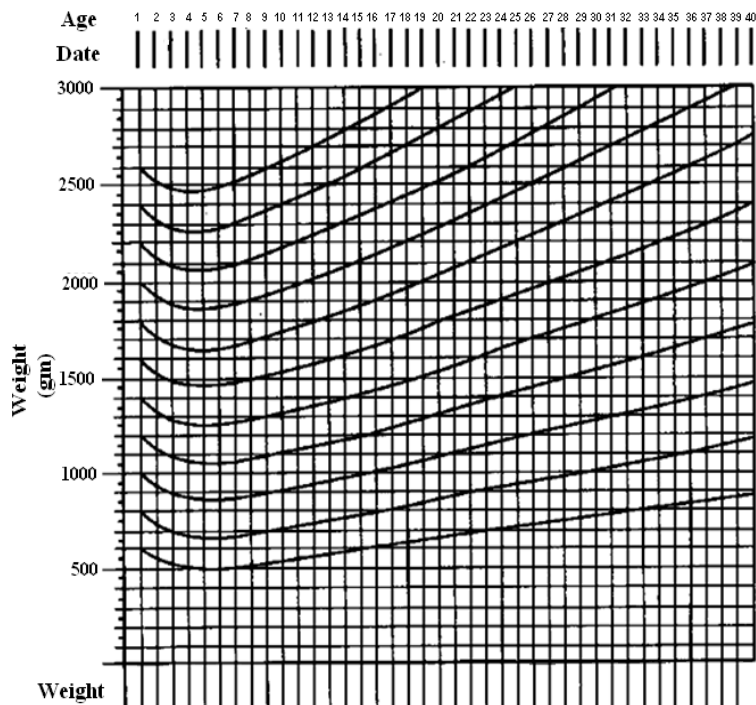


Figure (A5-1): Extrauterine growth chart

From Shaffer SG, Quimiro CL, Anderson JV, et al. Postnatal weight changes in low birth weight infants. *Pediatrics* 198; 79 (5): 702. Reproduced with permission from Pediatrics

Blood Pressure Values in Neonates

Blood Pressure by Gestational Age

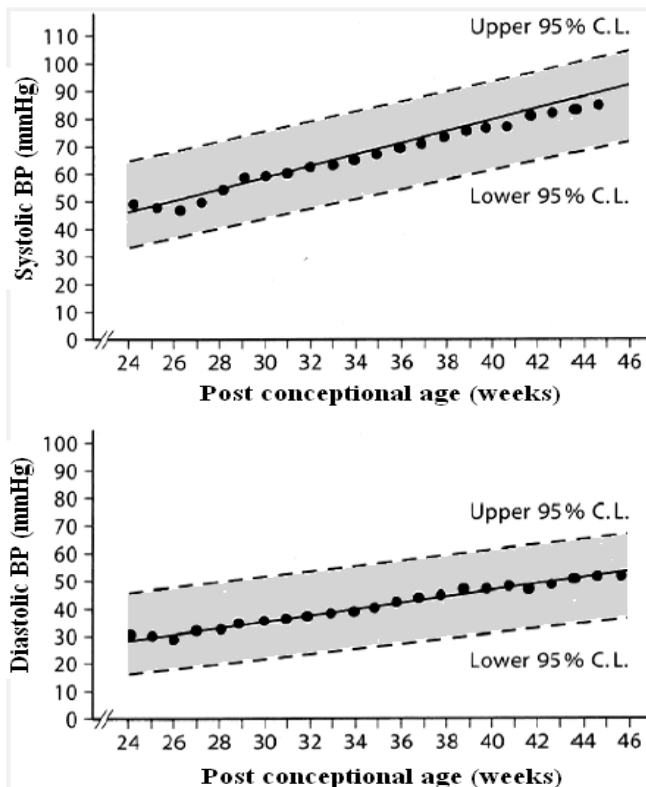


Figure (A6-1): Linear regression between gestational age & mean systolic (A) and diastolic (B) blood pressure, along with the upper and lower 95% confidence limits, which approximate mean \pm 2 SD

Zubrow AB, Hulman S, Kushner H, Falkner B. Determinants of blood pressure in infants admitted to neonatal intensive care units: A prospective multicenter study. *J Perinatol* 1995; 15: 470-479.

Blood Pressure by Post-Conceptual Age

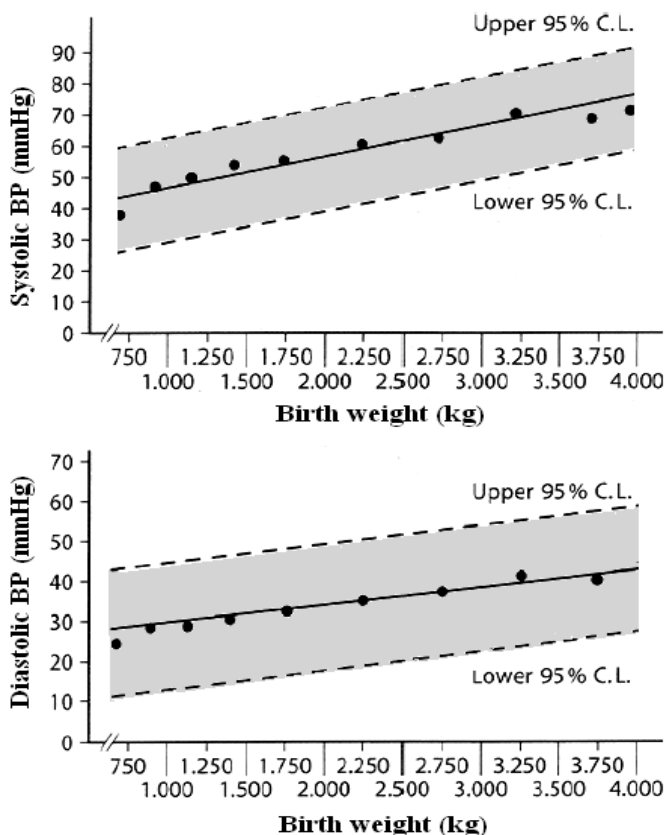


Figure (A6-2): Linear regression between post-conceptual age and mean systolic (A) and diastolic (B) blood pressure, along with the upper and lower 95% confidence limits, which approximate mean \pm 2 SD

Zubrow AB, Hulman S, Kushner H, Falkner B. Determinants of blood pressure in infants admitted to neonatal intensive care units: A prospective multicenter study. *J Perinatol* 1995; 15: 470-479.

Normal Laboratory Values in Neonates

Table (A7-1): Serum Electrolytes and Other Values in Term Infants

	Cord Blood		2- to 4-Hour Blood	
	Mean \pm SD	Range	Mean \pm SD	Range
Na ⁺ (mEq/L)	138 \pm 3	129–144	137 \pm 3	130–142
K ⁺ (mEq/L)	5.3 \pm 1.3	3.4–9.9	5.2 \pm 0.5	4.4–6.4
Glucose (mg/dl)	75 \pm 19	29–120	63 \pm 12	29–92
BUN (mg/dl)	6.0 \pm 1.7	3.0–10.0	7.1 \pm 2.0	4–12

BUN: blood urea nitrogen

Dollberg S et al. : A reappraisal of neonatal blood chemistry reference ranges using the Nova M electrodes. Am J Perinatol 18:433, 2001

Table (A7-2): Serum Electrolytes and BUN Values in Preterm Infants

Constituent	Age 1 week		Age 3 weeks		Age 5 weeks		Age 7 weeks	
	Mean \pm SD	Range	Mean \pm SD	Range	Mean \pm SD	Range	Mean \pm SD	Range
Na ⁺ (mEq/L)	139.6 \pm 3.2	133–146	136.3 \pm 2.9	129–142	136.8 \pm 2.5	133–148	137.2 \pm 1.8	133–142
K ⁺ (mEq/L)	5.6 \pm 0.5	4.6–6.7	5.8 \pm 0.6	4.5–7.1	5.5 \pm 0.6	4.5–6.6	5.7 \pm 0.5	4.6–7.1
Ca (mg/dl)	9.2 \pm 1.1	6.1–11.6	9.6 \pm 0.5	8.1–11.0	9.4 \pm 0.5	8.6–10.5	9.5 \pm 0.7	8.6–10.8
BUN (mg/dl)	9.3 \pm 5.2	3.1–25.5	13.3 \pm 7.8	2.1–31.4	13.3 \pm 7.1	2.0–26.5	13.4 \pm 6.7	2.5–30.5

Thomas JL et al: Premature infants: Analysis of serum during the first seven weeks. Clin Chem 14:272, 1968.

Table (A7-3): Plasma Creatinine in Term and Preterm Infants (mean \pm SD)

Age (day)	< 28 weeks	28–32 weeks	32–37 weeks	>37 weeks
3	1.05 \pm 0.27	0.88 \pm 0.25	0.78 \pm 0.22	0.75 \pm 0.2
7	0.95 \pm 0.36	0.94 \pm 0.37	0.77 \pm 0.48	0.56 \pm 0.4
14	0.81 \pm 0.26	0.78 \pm 0.36	0.62 \pm 0.4	0.43 \pm 0.25
28	0.66 \pm 0.28	0.59 \pm 0.38	0.40 \pm 0.28	0.34 \pm 0.2

Rudd PT, Hughes EA, Placzek MM, et al. Reference ranges for plasma creatinine during the first month of life. Arch Dis Child 1983; 58: 212–215.

Table (A7-4): Hemoglobin Changes in Babies in the 1st Year of Life

Hemoglobin level (gm/dl)			
week	Term Babies	Premature Babies (1,200-2,500 gm)	Premature Babies (<1,200 gm)
0	17 (14-20)	16.4 (13.5-19)	16 (13-18)
1	18.8	16	14.8
3	15.9	13.5	13.4
6	12.7	10.7	9.7
10	11.4	9.8	8.5
20	12	10.4	9
50	12	11.5	11
Lowest Hb: mean (range)	10.3 (9.5-11)	9 (8-10)	7.1 (6.5-9)
Time of nadir	6-12 weeks	5-10 weeks	4-8 weeks

Mentzer WC, Glader B. Erythrocyte disorders in infancy. IN: Taeusch HW, Ballard RA, Gleason CA, eds. Avery's Diseases of the newborn, 8th ed., Philadelphia, Elsevier, 2005.

Table (A7-5): Leukocyte & Differential Count during the 1st Month of Life

Age	Total Leukocytes*	Neutrophils		Lymphocytes		Monocytes		Eosinophils	
	Mean (range)	Mean (range)	%	Mean (range)	%	Mean	%	Mean	%
Birth	18.1 (9-30)	11 (6-26)	61	5.5 (2-11)	31	1.1	6	0.4	2
12 hr	22.8 (13-38)	15.5 (6-28)	68	5.5 (2-11)	24	1.2	5	0.5	2
24 hr	18.9 (9.4-34)	11.5 (5-21)	61	5.8 (2-11.5)	31	1.1	6	0.5	2
1 wk	12.2 (5-21)	5.5 (1.5-10)	45	5.0 (2-17)	41	1.1	9	0.5	4
2 wks	11.4 (5-20)	4.5 (1-9.5)	40	5.5 (2-17)	48	1.0	9	0.4	3
4 wks	10.8 (5-19.5)	3.8 (1-8.5)	35	6.0 (2.5-16.5)	56	0.7	7	0.3	3

*Numbers of leukocytes are $\times 10^3/\mu\text{L}$.

Cairo MS, Brahuo F: Blood and blood-forming tissues. In Randolph AM (ed): Pediatrics, 21st ed. New York, McGraw-Hill, 2003.

Table (A7-6): Normal CSF Findings in Newborn Infants

CSF Findings	Normal Values
Cell Count (WBCs/mm³)	
Preterm (mean)	9.0 (0 - 25.4)-57% PMN
Term (mean)	8.2 (0 - 22.4)-61% PMN
Glucose (mg/dl)	
Preterm	24-63 (mean, 50)
Term	34-119 (mean, 52)
CSF Glucose/Blood Glucose (%)	
Preterm	55-105
Term	44-128
Protein (mg/dl)	
Preterm	65-150 (mean, 115)
Term	20-170 (mean, 90)

PMN: polymorphonuclear leucocytes

Sodium and Glucose Solutions

Table (A8-1): Sodium Concentration in Various Solutions

Solution	Na Concentration (mEq/L)
3% NaCl in water	513
0.9% NaCl in water	154
Ringer's lactate	130
0.45% NaCl in water	77
0.2% NaCl in water	34

Table (A8-2): Preparation of Different Glucose Concentrations

Desired Glucose Concentration	Preparation of 100 ml
Glucose 5%	Ready made
Glucose 7.5%	50 ml Glucose 10% + 50 ml Glucose 5%
Glucose 10%	Ready made
Glucose 12.5%	37.5 ml Glucose 25% + 62.5 ml Glucose 5%
Glucose 15%	50 ml Glucose 25% + 50 ml Glucose 5%
Glucose 17.5%	50 ml Glucose 25% + 50 ml Glucose 10%
Glucose 20%	75 ml Glucose 25% + 25 ml Glucose 5%
Glucose 25%	Ready made
Glucose 30%	50 ml Glucose 50% + 50 ml Glucose 10%
Glucose 50%	Ready made

Important Points in Neonatal Radiology

The need for radiographs should be weighed against the risks of exposure of the neonate to radiation.

The neonate's gonads should be shielded as much as possible.

Any person holding the infant during the x-ray procedure should also wear a protective shield.

Normal Neonatal Chest X Ray Findings

- Lung fields appear symmetrically aerated.
- Costophrenic angles are clear.
- Diaphragm is at the level of the posterior arc of 8th rib posteriorly and 6th rib anteriorly.
- Cardiothoracic ratio (**Figure A9-1**) should be <0.6 ; evaluation of heart size should consider the degree of inspiration, judged from the level of the diaphragm.
- Increased pulmonary vascularity is not always apparent in the chest x-ray film. Reduced pulmonary blood flow is easier to detect and indicates serious cyanotic CHD.
- Thymic shadow may show a classic “sail” sign or may have undulant or smooth borders on the upper mediastinum.

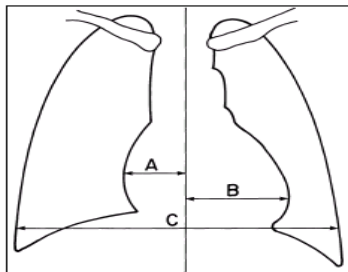


Figure (A9-1): Measurement of the cardiothoracic ratio from the postero-anterior view of a chest x-ray film

[The cardiothoracic ratio is obtained by dividing the largest horizontal line of the heart (A+B) by the longest internal diameter of the chest (C)]

N.B.1: Rotation of the neonate may erroneously suggest that there is cardiomegaly, or mediastinal shift.

N.B.2: Dextrocardia: the cardiac apex is on the right and the aortic arch and stomach bubble are on the left.

Catheters, lines and tubes

- Endotracheal tube
 - ▶ ETT tip should be positioned halfway between the medial ends of the clavicles and the carina (1 – 2 cm above the carina); it is important, that the neonate's head be in its natural position.
- Umbilical arterial catheter
 - ▶ A correctly positioned umbilical arterial catheter should lie in the lower aorta (at the level L3-L4) or above the diaphragm (higher than T12; between T6 and T9).
 - ▶ The catheter turns downward and then upward (the upward turn is the point at which the catheter passes through the internal iliac artery).
- Umbilical venous catheter
 - ▶ The catheter tip should be at the junction of the inferior vena cava and right atrium, projecting just above the diaphragm.
- Intercostal tube
 - ▶ Insertion sites are the anterior chest wall through the 2nd or 3rd intercostal spaces directly lateral to the mid-clavicular line, and the lateral chest wall through the 4th, 5th or 6th intercostal spaces directly anterior to the axillary line.
 - ▶ The tube should be inserted ~ 3 cm into the thoracic cavity and directed towards the apex of the lung.
- Feeding tube
 - ▶ The tip of the nasogastric/orogastric tube should be identified within the stomach or, where a nasojejunal feeding tube is used, within the jejunum.

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